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Preliminary insights into prehistoric toolstone preference of two igneous materials in the Tanana River drainage, interior Alaska

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Preliminary Insights into Prehistoric Toolstone Preference of Two Igneous Materials in the
Tanana River Drainage, Interior Alaska

An Honors Program Project Presented to
the Faculty of the Undergraduate
College of Arts and Letters
James Madison University

by Brooks Ann Lawler

April 11, 2016

Accepted by the faculty of the Department of Sociology and Anthropology, James Madison University, in partial fulfillment of the requirements for the Honors Program.

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Abstract

This project examines prehistoric human mobility and raw material preference for tool manufacture in a 45,918 square mile portion of Interior Alaska, the Tanana River Drainage. A geographic approach is used to investigate the distribution of prehistoric obsidian and rhyolitic artifacts in relation to the sources of these materials. The objective of the investigation is to reveal spatial patterning in the distributions of artifacts made of these two materials, relative to each other and relative to the cost of obtaining these raw materials from their sources on the landscape. I examine a hypothesis based in human behavioral ecology and optimal foraging theory, that if prehistoric hunter-gatherers acted to optimize their energy expenditure they could be expected to favor raw materials with the lowest cost of acquisition. Thus we may expect that a given site will contain a significantly higher proportion of low cost materials than high cost materials. The frequencies of different raw material types are examined for thirty-five sites with artifact assemblages that have identified source groups. Those frequencies are compared with geographic information systems models of travel cost. The results of the analysis suggest that the hypothesis does not represent a complete picture of prehistoric human behavior. Divergence from the hypothesis is explained with respect to the relative quality of the raw materials and the inventory of tool types of each material at the sites. A more realistic model of human behavior that was concluded from additional analyses was that prehistoric hunter-gatherers may have exploited group A rhyolite opportunistically while foraging along the mountain ridges in the summer, and obtained Wiki Peak and Batza Téna obsidian while following game along the frozen Tanana River in the winter.

Acknowledgement

This thesis was inspired by the extensive research on the raw material sourcing of rhyolite toolstone in Interior, Alaska by Sam Coffman, M.A. and Dr. Jeff Rasic. Since, there has been a focus on researching obsidian toolstone in Alaska, Sam Coffman offered me a wonderful opportunity to compare the prehistoric use of rhyolite and obsidian toolstone in the Tanana River Drainage. I offer my sincere gratitude to the University of Alaska, Museum of the North for providing me with the datasets used in this study and Sam Coffman for his extensive input and guidance through my thesis research and writing.

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Introduction

Archaeologists are interested in understanding how hunter-gatherers traveled across the landscape to obtain food and other resources. Stone tools are the most durable and prevalent records of hunter-gatherer lifeways, and therefore provide the most promise for understanding hunter-gatherer mobility (Andrefsky 2009). A stone that has been modified or worked by humans is often called a *lithic*. This term includes formal stone tools as well as the debris and flakes that result from making a tool. The ability to locate the source of stone used to make a stone tool allows archaeologists to determine the distance from the location where the stone was acquired to the artifact's final location.

Various studies have examined the raw material procurement strategies and curation of stone tools by means of lithic source analysis (Plains Anthropologist 1980; McAnany 1988; Milne et al. 2011). While other studies have used the knowledge of raw material source locations to investigate the relationship between the distribution of stone tools and the distance to their raw material sources (Taliaferro et al 2010; Eerkens et al. 2007; Beck et al. 2002).

The circumpolar region, especially Alaska, is a central area for the study of prehistoric human mobility because the landscape is associated with early human migration into North America. Therefore, archaeologists have put a significant amount of effort into understanding the subsistence patterns and human movement across the Alaskan landscape throughout history. Research often focuses stone artifact form, function, and distribution to answer questions about human mobility.

Alaskan archaeologists have focused a considerable amount of attention on obsidian (Reuther et al. 2011; Clark 1972; Cook 1995; Clark and Clark 1993) a high quality igneous raw

material that is common in site assemblages throughout eastern Beringia and in Siberia. Eight obsidian sources have been chemically identified in the region, including the three most pervasive raw material sources from which 65% of all obsidian artifacts are derived (Bennowitz et al. 2015). However, until recently less attention has been given to the study of other raw materials used by Alaskan hunter-gatherers such as rhyolite (Coffman and Rasic 2015), chert (Mull 1994), and basalt (Rains 2014). Since, rhyolite is relatively common in site assemblages in Interior Alaska, data on rhyolite sources can offer a more complete picture of raw material use and prehistoric human mobility. Geochemical analyses of rhyolite artifacts have begun for site assemblages in Interior Alaska. Rhyolite source groupings are currently being matched to locations on the landscape (Coffman and Rasic 2015). The source location of most widespread rhyolitic toolstone, Group A rhyolite, has been closely estimated to central Alaska Range, in the Tanana River Drainage, in Interior, Alaska (Figure 1.1). Therefore, this project examines the distribution of rhyolite and obsidian stone artifacts in relation to their raw material sources in the Tanana River Drainage (Figure 1.2).

Geochemical analysis of stone tools is used to derive the source of the stone by revealing the concentration of different elements within a particular rock type. Each source, either obsidian or rhyolite, is comprised of different proportions of these trace elements and thus constitutes a particular geologic source on the landscape. These data provide archaeologists with two important pieces of information: (a) The location of where the raw material originated; and (b) the final place the stone tool was discarded. The life-history of the artifact, including its manufacture, use, retouch, and discard contribute to the understanding of lithic technological

organization, which can be employed to assess prehistoric movement between (a) and (b) (Andrefsky 2009).

The knowledge of each raw material source location and the location of artifacts made from those sources combined with a digital model of the landscape allows for the use of Geographic Information Systems (GIS) technology to model the cost of travelling from sources to the sites where the artifacts were ultimately deposited. This study tests the hypothesis that, all else considered equal, hunter-gatherers sought to minimize the cost of obtaining raw materials. Hunter-gatherers thus can be expected to favor sources of raw materials that have “low cost;” easily accessible. An efficient raw material acquisition strategy should show the following pattern: assemblages should consist primarily of materials obtained from the least “costly” sources. Artifacts made of higher cost materials should be rare or absent. This study investigates inconsistencies with this pattern through case studies involving the distribution specific tool types in relation to the sources on the landscape, drawing from lithic technological organization perspectives. The study concludes that prehistoric mobility is more complex than hypothesized and suggests raw material use is imbedded in foraging patterns.

This thesis begins with a brief review of the literature on human behavioral ecology, as well as, other archaeological examinations of the distribution of lithic artifacts in relation to raw material sources. It is followed by a summary of obsidian and rhyolite research in Alaska. Next, a description of the study area and the methodology used in the analysis is provided. The results include cost surface analyses from each source, raw material cost case studies using specific lithic features, percentage of different raw materials and tool types per site, and weight/maximum dimension comparison of raw materials. The progression of analyses

eventually led to the conclusions about prehistoric human mobility in the Tanana River Drainage. Finally, I make suggestions for future investigations considering the variables that limited this analysis, which could be examined in a master's thesis.

This study contributes to the understanding of prehistoric human patterns of movement and use of raw material in Interior, Alaska. Regional studies, such as this one, can offer a methodology for estimating prehistoric territorial extent, interaction, and subsistence strategies. This methodology can be used in a broader sense to understand how regional mobility is connected to the peopling of continents.

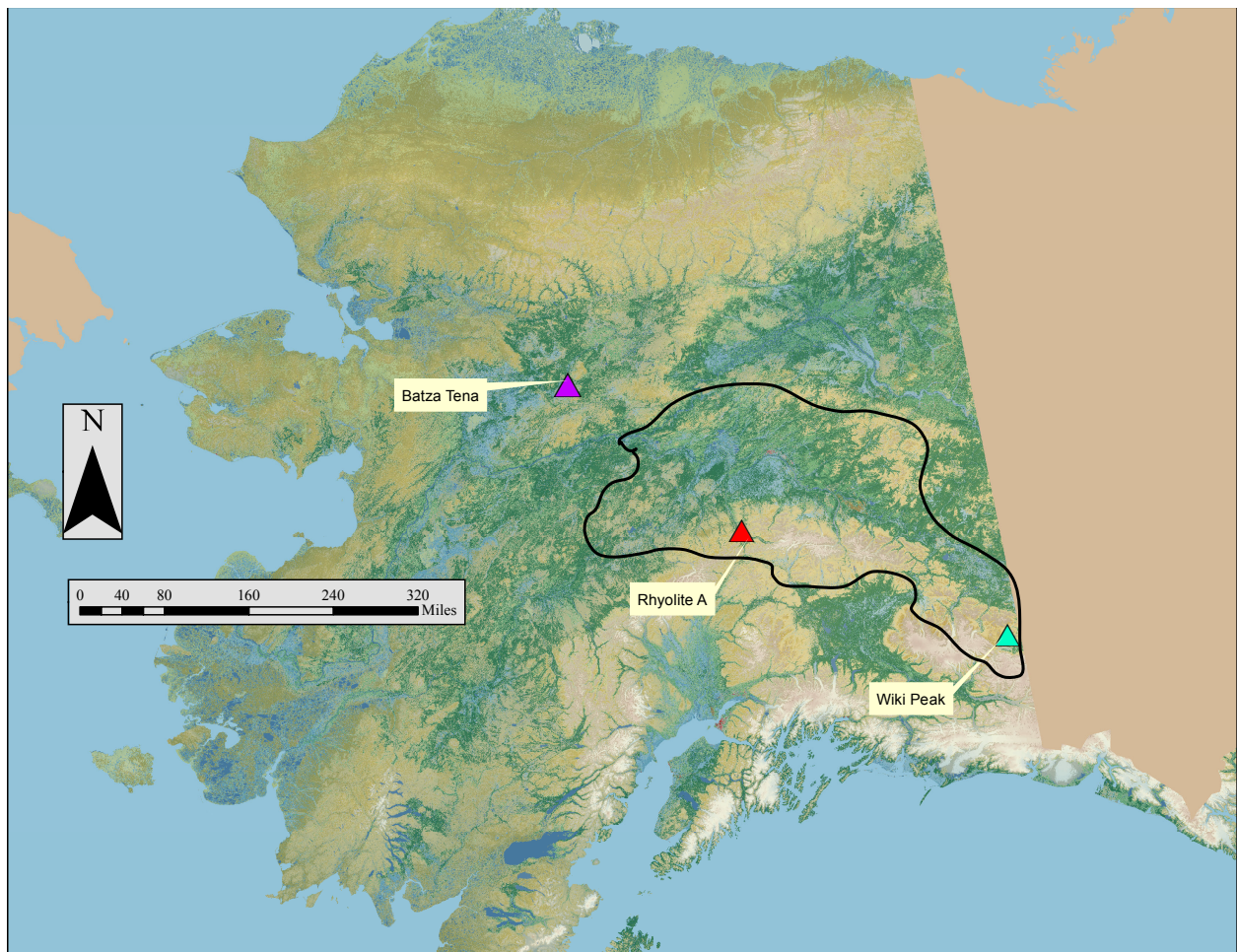


Figure 1.1 Location of the Tanana River Drainage and toolstone sources discussed in this study.

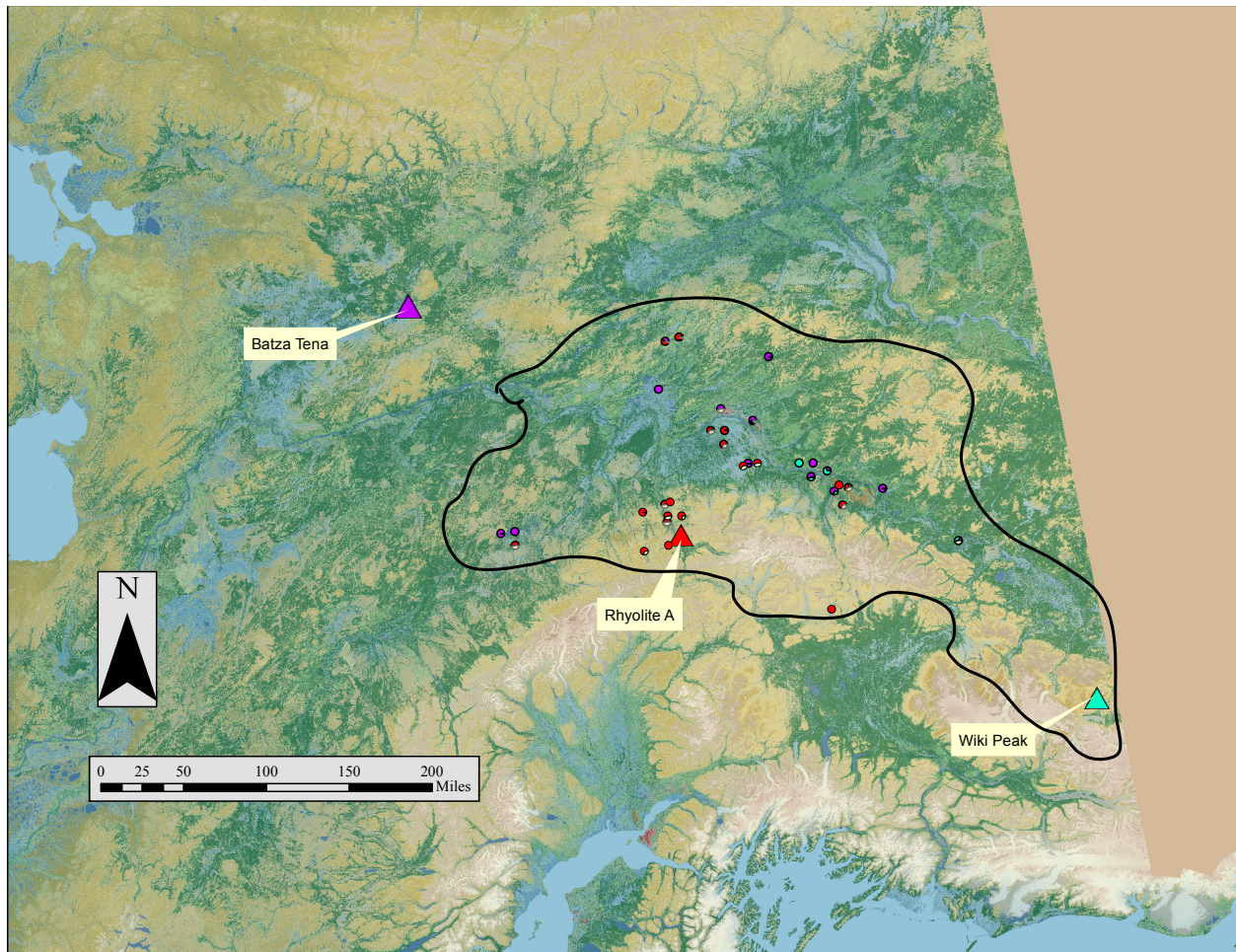


Figure 1.2 Location of sites analyzed in the study relative to toolstone sources.

Human Behavioral Ecology Approach

The archaeological study of stone tools has long been dominated by a typological approach. Typological approaches seek to classify stone tools in terms of their physical attributes, including shape, size, and technique of reduction, or the distinct ways in which prehistoric people reduced a piece of stone to a finished tool. Differences among stone tools have typically been attributed to style or function. Analyzing tools in terms of style assumes that prehistoric people, like modern hunter-gatherers, expressed social difference through varying

aspects of their tools with minimal effect on tool performance. Analyzing stone tools in terms of function assumes that tools used for different tasks should appear different. Although, typological approaches to lithics have had some success in revealing hunter-gatherer life-ways many questions remain. For instance, archaeologists would like to know the extent of hunter-gatherer territories, the spatial organization of their subsistence activities, and the scale of exchange relationships. One productive way to study stone tools is to examine the behaviors that form the life-history of an artifact, from its procurement to its discard (Bever 2000:75-78). In order to address dynamic questions about prehistoric human behavior, theoretical approaches drawn from evolutionary ecology may be suitably applied to the study of lithic technology. For instance, some archaeologists have proposed that examining the life-history of lithics from an evolutionary ecological perspective will result in understanding prehistoric mobility across the landscape by answering questions about human behavior and decision-making.

Evolutionary ecology studies an individual's behavior, life-history, and physique with regards to its ability to adapt to its environment in order to increase biological fitness. It therefore considers patterns of human behavior within the framework of biological evolutionary theory (Bird and O'Connell 2006:143 – 144). Human behavioral Ecology (HBE) is a subset of evolutionary ecology that examines patterns of fitness-related behaviors within a socioecological context (Bird and O'Connell 2006:144; Smith and Winterhalder 1992). Essentially, like all animals, humans need to survive (meet caloric requirements) and reproduce in order to be successful in an evolutionary sense. The strategies that maximize these capabilities can be passed on to subsequent generations through biological, behavioral, and cultural adaptations. This idea does not mean that all behaviors have adaptive benefits but most behaviors target optimization of

the individual's environment (Surovell 2009: 6-7). Though behavioral ecology is an interdisciplinary theoretical framework used by biologists, ecologists, and ethnographers to answer a wide breadth of questions regarding social, reproductive, and foraging patterns in animals and humans, when adopted by archaeologists it is most commonly used to address foraging communities and subsistence (Bird and O'Connell 2006). Generally, Human Behavioral Ecology (HBE) assumes that fitness is determined by an individual's capacity to solve fitness-related problems efficiently (Bird and O'Connell 2006). It creates models for optimal decision-making to reach a goal with respect to environmental and biological constraints of the organism (Surovell 2009:7). Therefore, according to Surovell (2009:9) HBE lends itself to the study of technological organization "because decisions must be made at virtually every stage of stone tool production and use, and those decisions can be modeled as optimization problems."

A collection of foraging theories within the behavioral ecological framework is known as "Optimal Foraging Theory" (OFT). When applied to humans optimal foraging models assume that individuals interact rationally and efficiently with their environment to maximize energy returns from their energy outputs in the context of subsistence procurement (Taliaferro et al. 2010: 537). These models attempt to mathematically analyze a decision that an animal is assumed to make based on the "best" possible outcome (Stephens and Krebs 1986: 6). Quantifiable variables, such as amount of stone cortex and distance it is transported, are used to frame the optimization problem. For instance, if the weathered cortex of stone is not useable for stone tool manufacture, it may be more energy efficient remove the cortex at the source rather than transport it back to a campsite (Metcalf and Barlow 1992). Technological investment directly relates to subsistence because of the time and energy costs required for stone tool

procurement, production, transport, and use to obtain calories by hunting (Ricklis and Cox 1993: 445). Based on this idea technological investment can be analyzed using OFT (Taliaferro et al. 2010: 538; Beck et al. 2002:488).

The Central Place Foraging model is one optimal foraging model that specifically targets the relationship between the transport of material (food, tools, etc.) and subsistence. It is often used to predict the prey size and degree of processing of food depending on its distance from the central place, such as a residential site. The relationship between a resource and distance from the central place can be measured by using quantifiable variables such as time, weight, and some measure of utility e.g. energy, nutrients (Bettinger et al. 1997: 888). Metcalfe and Barlow (1992) create a central place foraging model to investigate field processing of prey, by examining the cost trade-offs of removing the shell of a nut as it is collected verses carrying the entire nut back to the central place. Metcalfe and Barlow (1992) can be adapted to model raw material procurement and tool manufacture (Beck et al. 2002). Specifically, the central place models assumes that the archaeologist knows the central site to which the humans returned and the form of mobility (logistical or residential) during the time period of study. Residential mobility is the term given to a mobility strategy when all members of the residential camp move and relocate the camp in order to obtain resources. Logistical mobility refers to the movement of individuals or small groups of people from a residential camp to obtain resources, for example, hunting bands. (Binford 1980; Kelly 1983: 278). Other studies, such as Chapman et al. (1989), discuss the implications of multiple residential sites rather than a central place on cost. This study assumes the basic idea of central foraging theory when examining the effect of cost distance from a raw material source to each individual site. Since residential and logistical mobility are

undefined by this dataset this study assumes each individual site serves as an independent central place.

The study attempts to find a general pattern in the distribution of raw material from a source that shows the amount of material decreases with cost distance from the source based on central foraging theory. According to Smith et al. (1983:626), “An optimal foraging model must specify a currency (such as energy), a goal (such as maximizing foraging efficiency), a set of constraints (factors that limit the range of options for the duration of the process studied), and a set of options (choices left open to the actor).” In this study the currency is time, the goal is maximizing foraging efficiency, the constraints consist of terrain (distance and slope), the option is to use toolstone that is the least costly to acquire.

Although Optimal Foraging Theory has been used to predict hunter-gatherer diet choice, optimal group size, foraging location choice, etc., Smith et al. (1983), has shed light on the critiques of OFT. Most commonly OFT is critiqued for its simplicity when describing the cognitive complexity of human foraging decisions, which could include cultural influence, such as religious significance of a resource. Additionally, the validity of simple currency models when describing efficiency is questionable due to not knowing which and how many currencies and constraints were actually at work in the past (Smith et al. 1983:638-639).

Despite these criticisms Smith et al. (1983), suggests despite the difficulties of using OFT to answer the social aspects of human foraging, it can be enhanced by other frameworks to create a more complete representation of human foraging. These models are helpful for initiating an empirical and quantitative investigation of questions about raw material acquisition and use in Interior, Alaska. Human behavioral ecology is chosen as a starting theory for this study because

it can be assumed that the harsh prehistoric environment in Alaska would have created fitness-related constraints that exerted pressure on small populations of foragers, which would require them to optimize their net energy gain. This project exemplifies the need to aid OFT by taking into account other factors, such as social trade networks, hunting patterns, raw material flaking properties, raw material preference and social/religious value that influence prehistoric human foraging behavior.

Raw Material Sourcing

Raw material occurs naturally on the landscape and is the geographic “starting point” of a stone tool’s life-history. Raw material sourcing is common in the study of stone tools (Eerkens et al. 2007, Hatch et al. 1990) as well as clay (Shepherd 1965).

This study uses two major obsidian toolstone source locations and the approximate location of a source of rhyolite toolstone, which were all determined by comparing the geochemical and physical properties of stone tools to the raw materials on the landscape. There are a number of ways to determine the source of a stone; methods range from qualitative microscopic analysis (Milne et al. 2011:125; Odell 2004: 28) to geochemical analysis (Glascok et al. 1998; Phillips and Speakman 2009). Volcanic (igneous) stone is particularly apt for geochemical analysis because all forms consists of eight elements (oxygen, silicon, aluminum, iron, calcium, sodium, potassium, and magnesium), but different types of igneous stone will have different proportions of these elements (Andrefsky 2005:47). Obsidian is an extremely rapid cooling subcategory of rhyolite, thus both materials are igneous in origin but contain distinct geochemical signatures. Therefore, they offer archaeologists an opportunity to look at human mobility because both

materials are amenable to geochemical characterization by measuring the amounts of trace elements within a particular sample. Additionally, rhyolite and obsidian “can be chemically homogeneous within its source flow yet chemically discernable between source areas” (David and Thomas 2008: 531). These attributes of rhyolite and obsidian contribute to the ability to “pin-point” these sources on the landscape. There are a number of popular techniques for geochemical analysis of raw material. The datasets within were derived largely from pXRF (portable X-ray fluorescence) analysis. A technique similar to XRF (X-ray fluorescence spectrometry) but is non-destructive making it optimal for archaeological studies.

Spatial Approaches to Stone Tool Analysis

The location of a raw material source combined with the provenience of the discarded tools from this source is the minimal distance that a human traversed between these two points, though the tools may have taken a more circuitous route to its final place of deposition. Studies can be developed from the knowledge of the distribution of artifact assemblages and their raw material sources to answer questions about territorial extent (Jones et al. 2003), raw material procurement and curation strategies and decision-making (Ricklis and Cox 1993, Smith 1999), trade networks (Kuzmin 2013), and toolstone preference (Wilson 2007). A common model to address cost of lithic transport and raw material choice is by comparing the properties of lithic assemblages to the distance to their sources (Ricklis and Cox 1993; Newman 1994).

Archaeologists often assume that lithic reduction increases with distance from the source and therefore the material amount should decrease as the distance from the source increases (Metcalf and Barlow 1992; Bird and Bird 1997: 44; Beck et al. 2002: 486). For example, the

initial reduction of a raw material in the process of tool manufacture should occur close to the source, while later re-sharpening of tools should occur farther from the source. In some regions such as prairies, plateaus, or otherwise flat landscapes with minimal obstacles distance may be an appropriate measure of cost associated with the transport of materials. However, in a mountainous environment like interior Alaska, the cost to obtain raw materials is best measured not in terms of linear distance (“as the crow flies”), but as a function of both the distance and slope from source to final location. For instance, it is more costly to traverse 1 mile uphill than 1 mile on flat ground.

A solution to the biases associated with using distance as an indicator of cost is cost surface analysis by means of Geospatial Information Systems (GIS). GIS technology is an analytical tool that allows archaeologists address theoretical questions in landscape archaeology (Ebert 2004: 320; Savage 1990: 22). There are a myriad of practical uses for cost surface analysis and path distance analysis, such as to find the best route for a hiking trail from the bottom to the top of a mountain, which can be adapted to predict optimal travel paths for prehistoric hunter-gatherers. GIS models can be explanatory such that they are based on hypothetical criteria relating to human behavior, or they can be predictive, such that they are used to estimate locations of human-made features on the landscape (Ebert 2004: 324). This study is considered to be an explanatory GIS model since it uses optimization criteria derived from OFT to explain the distribution of lithic technology on the landscape in terms of human behavior.

One critique of using GIS models to assess prehistoric movement across the terrain, as stated by Ebert (2004: 324), is that it is impossible to account for all the conditions that are

considered in land-use decisions. Additionally, when using these models to study prehistory, it is often assumed that the landscape was the same in the past. However, GIS cost surfaces analyses, a spatial analyst tool extension in ArcMap (ESRI 2014), can address a greater number of variables associated with walking on the landscape, that would have otherwise been unknown if cost of travel was solely based on distance. More recent models address this issue and offer approaches that take into account terrain (Whitely and Hicks 2003; Wilson Fall 2007; Wilson December 2007). Cost can be attributed to slope, bodies of water, dense forests etc. The more detailed the better it would represent actual human movement across the landscape.

Project Background

Tanana River Drainage Landscape

This study focused on the Tanana River Drainage in Interior, Alaska. The stone tool materials in the site assemblages are analyzed in relation to their raw material sources. Of the three raw material sources examined in this study group A rhyolite, Batza Téna, and Wiki Peak, two are located in the Tanana River Drainage (Figure 1.1). Batza Téna is the only source not located within the Tanana River Drainage but is located near the Koyukuk River in Northern, Alaska south of Gates of the Arctic Park and Preserve. Wiki Peak is located in the Wrangell Mountains of Wrangell St. Elias National Park and Preserve. Rhyolite A is thought to geologically occur in the central Alaska Range, in the proximity of Sugarloaf Mountain. All the sites examined in this study are also located in the Tanana River Drainage (Figure 1.2). Since this study seeks to understand prehistoric human movement and raw material use across this region it is important to know the general environmental and geological features of the landscape.

The Tanana River flows northwest from the Wrangell Mountains 379 km into the Yukon River north of Fairbanks, and is approximately 1,060 km long with a watershed that is larger than Virginia. The Tanana River Valley is 17,400 square km (Mason and Begét 1991: 393; Rozell 2015). The Tanana Valley itself is bordered on the south by the Alaska Range and the Yukon-Tanana upland to the north. Other major tributaries of the Tanana River include the Nenana River and the Teklanika River along with the Nebesna River, and Delta River all allowing passage to the north edge of the Alaska Range. The Tanana River is very wide and braided. Braided rivers with significant gravel bars create somewhat of a natural highway for

animal mobility since the flat gravel bars are easy walking routes. The vegetation consists of boreal forests (marshy areas of black spruce) and tundra (Hadleigh West 1996: 295). The climate of the Tanana Basin is characterized by harsh, extremely cold winters and warm summers (Hadleigh West 1996: 295). Additionally the river is frozen from late October through April (Wada et al. 2011: 633).

Large game animals such as bison, elk, sheep, birds, and some fish were exploited the most during the Late Pleistocene (12,000 – 14,000 BP) and Early Holocene (6,000 – 12,000 BP) but decreased over time. Sheep reappeared as a resource in the archaeological record as well as some instances of bison during the late Holocene (0-1000 BP). Fish, caribou, moose, and medium to small mammals such as rabbits seem to be exploited more starting in the middle Holocene (1,000-6,000 BP) and late Holocene (Potter 2008a:190-191). There are 18 fish species indigenous to the Tanana River Drainage, the most popular for consumption include king and silver salmon, Arctic grayling, burbot, lake trout, and northern pike (Alaska Department of Fish and Game).

Archaeological sites in this region are often located on bluffs overlooking the rivers (referred to as “blufftop lookout” sites), the rolling foothills of the Alaska Range, or the aeolian (sand/silt) deposits along the Tanana River (Hadleigh West 1996) (Figure 1.2). The oldest sites in the Tanana River Valley include Broken Mammoth, Mead, and Swan Point with evidence of occupation between 14,000 and 13,000 years BP and are noted for broadly based hunting and foraging economies (Holmes 2001: 154). Archaeologists suggest that the “blufftop lookout” sites show occupational seasonality. In most cases these “blufftop lookout” sites were thought to be hunting camps where small groups were sent out from the villages in the river valley bottoms to

watch for game (Guthrie 1983:268). However, since the discovery of the Broken Mammoth site, which is a “bluff-top lookout site” containing extensive evidence for long-term occupation, it is suggested that some of these “bluff top” lookout sites may represent long-term seasonal occupations (Yesner 2001:319). Healy Lake site is the only site that is thought to be a permanent village, the rest of the sites seem to not be long term villages but occupied for a portion of a year by “supra-nuclear” family units, such as multiple households, to exploit large game herds and the local microenvironments (Yesner 2001:319). Population levels in the Tanana Valley appear to be correlated with glacial retreat and advancement from 14,000 – 12,000 BP and later population decrease in the early Holocene correlated with a warming climate (Potter 2008a:187).

Cultural History of in Interior Alaska

Early in lithic studies archaeologists focused on compiling data on tool form within assemblages in a given time period. They used this data to recognize patterns in tool form on a regional scale. When archaeologists recognized a strong pattern they would designate the pattern as a regional technology or complex. Then these complexes were assigned to a culture of a group of people. In order to discuss the distribution of stone tools in the Tanana River Drainage, it is helpful to understand the history and interpretation of initial typological stone tool complexes in the study region. These stone tool “complexes” are often still referred to in the literature about stone tool studies and technological organization in Alaska.

The Nenana Complex, an Alaskan technological tradition local to the northern foothills of the Alaska Range, dates to between 11,500 and 11,100 BP and was once considered the earliest known technological tradition in North America. (Powers and Hoffecker 1989: 284,

Goebel et al. 1991, Bever 2001). The Nenana Complex is defined by Powers and Hoffecker (1989) as a local toolkit with the presence of bifaces and absence of microblades. Archaeologists have identified later complexes of interior Alaska (such as the Denali Complex 10,600 – 7,000 B.P.) on the basis of morphological similarities of tool assemblages such as the presence or absence of distinctive stone tool forms. Hadleigh-West (1967) originally defined the Denali Complex as a regional variant, distinctive to Alaska, of a widespread microblade technology of northeastern Asian and Northwestern America during the Late Pleistocene/Early Holocene (Fagan 2005:172, Powers and Hoffecker 1989:272). Therefore, the presence of microblade technology was used to define the Denali Complex (Dixon 2001).

The cultural significance of these two different complexes is poorly understood; differences in tools may be purely stylistic or may be due to differences in the tasks their users performed. For instance, a significant site in Alaska named Swan Point led to a completely different interpretation of these complexes when distinct tear-dropped shaped, bifacial Chindadn Points characteristic of the Nenana Complex were found stratigraphically above microblade technology, which is distinctive of the Denali Complex. Additionally, at other sites these two tool forms were found to be contemporaneous (Bever 2001, Potter 2008). Revised interpretations suggest that these two spacio-temporal co-occurring Alaskan complexes are variants of one cultural system (Bever 2001). Differences between the Nenana and Denali Complex may be due to differences in site function (Bever 2001) or the changing environment at the end of the Pleistocene, when hunter-gatherers shifted from a focus on large mammals to a more broad-spectrum adaptation (Holmes 2001: 153-154).

More recent technological traditions in interior Alaska include the Northern Archaic Tradition and late prehistoric Athapaskan Tradition. The Northern Archaic Tradition was estimated to occur in the Tanana Valley between 4,600 and 3,400 BP and was identified by notched projectile points (Dixon 1985). The late Athapaskan Tradition was estimated to occur in the last 900 to 400 years consisting stone tool technology made of materials that were possibly traded and pottery. Later post-contact Athapaskan traditions contain copper tools and ornaments in addition to stone tools (Dixon 1985).

Obsidian Studies in Alaska

The use of obsidian by hunter-gatherers is well studied throughout the Arctic. Analyses have been performed on obsidian artifacts and source material since the late 1960s and many sources have been geochemically analyzed and identified. Research has recently shifted from identifying sources to testing ideas about human behavior and cultural processes (Reuther et al. 2011:270), including the recognition of prehistoric exchange patterns (Cook 1995:99) and differential preference for particular sources (Slobodina et al. 2009:117).

Obsidian studies have helped archaeologists piece together pictures of prehistoric mobility and trade. Studies of obsidian in Northeast Asia have identified the use of obsidian as toolstone as early as 15,000 ca. radiocarbon years ago and identified obsidian exchange patterns (Kuzmin 2006). In Alaska, artifacts have been located for all eight geological sources of obsidian. However, 65% of all obsidian artifacts in sites throughout Siberia, Alaska, and the Yukon have been sourced to Batza Téna in arctic Alaska, Wiki Peak in southeast Alaska, and Okmok caldera on the Aleutian islands (Bennowitz et al. 2015).

The Batza Téna obsidian source was first located and published with this name in 1970 by Dr. W. W. Patton and Thomas Miller, however it had been spoken of by Athabaskan informants prior to its documentation (Clark 1972). This was the first obsidian source identified as the material of artifacts in Interior and Northern Alaska. The early studies of Batza Téna obsidian describe the sites and artifacts in the general locality of the source (Clark 1995). These sites are dominated by Batza Téna obsidian tools, for example, in the assemblages there are twelve chert flakes in comparison to 22,440 obsidian flakes (Clark 1972). Furthermore, Batza Téna obsidian is extremely widespread in site assemblages across Alaska and is found as far as 930 kilometers from the source (Reuther et al. 2011:274).

It is widely accepted that obsidian, especially Batza Téna obsidian, was traded throughout prehistory as early as the 13,500 years ago, suggesting early interaction among widespread social groups (Holmes 2001; Goebel et al. 2008). Chris Houlette has studied the distribution of Batza Téna obsidian artifacts in the Gates of the Arctic National Park in relation to the ethno-historic Athabaskan and Eskimo seasonal round and trade routes. He discovered that the prehistoric obsidian assemblages fell along these same routes suggesting that prehistoric humans may have traveled across the landscape similar to recent travel (Houlette 2009). The wide distribution of Batza Téna material and studies related to its trade, provide a picture of Late Pleistocene hunter-gatherer interaction through the development of exchange networks that persisted into the historic period, or reveals extremely large-scale mobility (Goebel et al. 2008).

While, obsidian is a prominent lithic material in assemblages throughout Alaska, the proportion of obsidian tools to tools made of other materials is low in sites in central Alaska. There are 764 artifacts that were recorded with a lithic classification made of obsidian from the

sites in the Tanana River Drainage. In comparison there are 518 artifacts made of rhyolite that were recorded in the Alaskan Rhyolite Database for the Tanana River Drainage, however this only includes a sample of the rhyolite present in several sites (cf. Methods: Dataset p. 40).

Therefore, locating sources of other lithic materials, such as rhyolite, will create a more complete picture of prehistoric raw material use, transport, and hunter-gatherer movement.

pXRF of Rhyolite and Source Estimation

Rhyolite is another material procured for stone tool manufacture in the Arctic, and found on Tanana Valley Sites. Since rhyolite is an abundant material of tools in interior Alaska, the study of rhyolite is important to form a complete picture of prehistoric mobility, subsistence, and tool use (Coffman and Rasic 2015:1). However, the study of rhyolite has been less extensive than obsidian and is currently in the initial stages. Enough has been done thus far such that ten distinct groupings have been geochemically identified. Two of these sources have been located on the landscape and others have been closely estimated. Researchers attempt to locate the toolstone quality rhyolite by re-locating and geochemically analyzing rhyolite deposits that have been documented and mapped by U.S. geological surveys. Rhyolite deposits are often recognizable on mountain faces, such as the peak of Sugar Mountain, which is made up of blocks and scattered outcrops of rhyolite (Plafker et al. 1963:51).

Coffman and Rasic used portable X-ray Fluorescence (pXRF) to analyze 676 rhyolite artifacts from 123 sites from Interior, Alaska. They defined 10 separate geochemical groups, known as rhyolite groups A – J, however only two sources that match the geochemical groups have been geographically identified. These are the two smallest groups, groups G and H. As a

starting point to locate the two largest groups, group A and group B, researchers estimated the locations based on the distribution of artifacts from these groups and their size and weight, assuming that more material would be located close to the source in terms of Euclidean distance (Coffman and Rasic 2015:1, 6).

Summer 2015 research aimed to “pin-point” the location of Group A rhyolite. Plafker et al. (1963) identified and documented a number of perlite outcrops in the Alaska Range. Perlite is a heavily weathered, decomposing form of obsidian/volcanic glass that is used for construction among other purposes. Perlite forms in a similar way as true obsidian and rhyolite, and was thought that tool quality rhyolite might be in the vicinity of these perlite outcrops. Fieldwork conducted at these outcrops in 2015, attempted to locate the geological outcrops described by Plafker et al. (1963) and sample the nearby rhyolite. Collected samples from fieldwork were then geochemically analyzed in an attempt to match artifacts to source material. The results of the fieldwork determined these rhyolitic outcrops near perlite were probably not a major resource in prehistoric Alaska. Due to the vastness of igneous flows, it is difficult to locate tool quality material. Due to these difficulties, researchers (e.g. Coffman and Rasic 2015, and Bennowitz et al. 2015) have gone about locating or approximating the locations of some of the rhyolite sources based on the presence/absence of cortex, and size and weight of artifacts, with the assumption that larger and heavier artifacts would be closer to the source material. Per these assumptions, they estimated Group A rhyolite is probably located in the vicinity of Sugarloaf Mountain, in central Alaska.

Samples collected at Sugarloaf in 2015 were determined not to be the exact source of Group A rhyolite, however based on geologic units of the area it is still largely believed the

material originated in the area. The levels of trace elements of the rhyolite collected from the deposits on and around Sugarloaf are very close to the geochemical signature of group A.

Therefore, the location of group A rhyolite is approximated to the headwaters of Moody Creek in along a tributary to the northeast of Sugarloaf Mountain (Image 2.1).



Image 2.1 The headwaters of Moody Creek and the estimated source location of group A rhyolite. The photo was taken looking east from the south ridge of Sugarloaf Mountain, August 2015.

Obsidian and Rhyolite as Toolstone

Obsidian and rhyolite are igneous stones that lend themselves well to knapping because of their flaking properties. The manner in which igneous rock forms contributes to its optimal flaking properties. Rhyolite and obsidian cool rapidly during formation, which contributes to their high silica content and relative lack of crystal formation. High silica content allows stones to fracture smoothly and conchoidally. Obsidian is a volcanic glass, which is formed from magma that cools extremely rapidly. This rapid cooling prevents any distinct crystals from forming, which contributes to its predictable fracturing properties that are preferred for stone tool manufacture (Whittaker 1994). According to Whittaker (1994), current flintknappers prefer obsidian because it is easy to control and flake, but because of its brittle nature it is easy to break during manufacture.

Understanding the flaking properties of these materials is important when patterns are recognized regarding the types of tools manufactured out of each material. It is possible that in some instances obsidian could have been preferred to make particular tools due to its sharpness. Smith (1999) best describes the appeals and disadvantages of obsidian as toolstone noting that it is easy to chip into tools with the sharpest edge, so would have been valuable for cutting tools that needed to be made quickly. However, it is brittle and dulls rapidly. Additionally, Smith (1999) suggests that tools made of obsidian do not differ from tools made of other materials, so tool function is probably not the only factor contributing to obsidian selection, however it could have been transported long distances because it was exotic and valued for its flaking properties.

Obsidian is technically a form of rhyolite but rhyolite is distinct from obsidian because its rate of cooling is slower, giving it a coarser texture. Additionally, not all rhyolite veins cool at

the same rate or form the same way. The slower the rhyolite cools the more minerals are able to be sorted into crystalline formations and therefore rhyolite can contain up to 50% quartz. This means that the flaking qualities of different rhyolites can be highly variable (Whittaker 1994). Therefore, particular veins of rhyolite may be better for tool manufacture and will be represented abundantly in the archaeological record, such as Group A rhyolite. Rhyolite, in general, is often good for tool manufacture because it cools rapidly during formation and contains more than 70% silica. Different from obsidian, microscopic crystals do form in rhyolite, which gives it a slightly coarser texture. The high silica content gives the rhyolite its light color and low density, which also is brittle and fractures conchoidally, making it optimal for tool manufacture (Coffman and Rasic 2015). Due to the variability in rhyolite flaking qualities and its slightly coarser texture than obsidian, rhyolite is usually not a good material for a beginner modern day flint-knapper for making fine tools (Whittaker 1994). However, it may be preferred in some cases because its coarser texture does not dull as quickly as obsidian, and therefore a tool made of rhyolite would need less maintenance and last longer.

The obsidian (Batza Téna and Wiki Peak) and rhyolite (Rhyolite A) sources in this study are located on very different landscapes ranging from rolling hills to rugged mountains. The difference in traversability of the source locations is reflected on the cost surface maps (Figures 4.13, 4.14, and 4.15), which show the amount of energy it takes, in time, to travel away from each source in any direction.

Batza Téna is the most studied and largest obsidian source in interior, Alaska. Batza Téna obsidian deposits are located few kilometers east side of the Koyukuk River, on a flat-topped ridge in a hilly area surrounded by tributaries of the Koyukuk (Clark 1995: 82; Clark and Clark

1993). According to Reuther et al. (2011:282), “Batza Téna is an extensive source area with abundant outcrops and secondary sources of obsidian. It is likely that Batza Téna was highly visible to prehistoric foragers.” The Batza Téna material itself is not found in the form of bedrock but rather round rubble fragments up to ten centimeters in length. Though the surfaces of these fragments can be weathered the fresh surfaces (interior) are glossy black (Patton and Miller 1970: 761).

Wiki Peak, the next most prominent obsidian source in interior Alaska, is noted for its difficulty to access due to its location in rugged terrain. According to the National Park Service, U.S. Department of the Interior, Yukon-Charley Rivers National Preserve, Obsidian Journeys poster the Wiki Peak obsidian source is located in the Nutzotin Mountains of Wrangell-St. Elias National Park near the southeast boarder between Canada and Alaska. It is suggested in this poster that people who lived in the Yukon-Charley Rivers region (National Preserve) obtained more obsidian from Batza Téna even though the preserve is closer to Wiki Peak. This was speculated to be the case because Wiki Peak obsidian would have been more challenging to obtain due to rugged terrain and the Yukon River was a more convenient route for trading Batza Téna obsidian (Yukon-Charley Rivers National Preserve).

Group A Rhyolite is the geochemical group associated with the greatest number of artifacts in the Tanana River Drainage (n=337), therefore this source is of most interested to locate. According to Coffman and Rasic (2015), group A rhyolite can be light grey, to pale purple, to yellowish/pale orange, and is fine-grained, homogeneous, glassy which makes it preferable for flintknapping, such that it could be used for manufacturing microblade technology. The estimated source location has been honed from the central part of the Alaska Range to a

location east of the Parks Highway near Sugarloaf Mountain and the headwaters Moody creek (Image 2.1). The area is characterized by sloping ridges of slate and tundra, which are home to a number of Dall sheep (Image 2.2). Further, rocky narrow creek drainages lead to access of the ridges (Image 2.3).

It is important to note that obsidian can be found in the tributaries coming off of the source location stones ranging from pebbles to softball sized cobbles. This is likely for rhyolite as well (Image 2.3). Prehistoric foragers possibly collected these materials from the tributaries in the direct vicinity of the sources. The ability to collect these materials from the tributaries may be an easier avenue for collecting raw material, however humans would have still have to traverse essentially the same topography in the immediate vicinity of the sources to obtain the raw materials.



Image 2.2 Herd of Dall sheep traveling along the east buttress of Sugarloaf Mountain. This photo also shows the tundra flanking the ridges of the mountains, and rhyolite and basalt outcrops.



Image 2.3 Headwaters of Moody Creek east of Sugarloaf Mountain, looking downstream. The image shows the narrow drainages that lead to the steep mountain ridges and raw material outcrops. It also shows how rhyolite pebbles and cobbles could end up in these creeks through erosion.

Methods

This study employs a regional approach to understand human mobility and tool procurement strategies using lithic data from the Tanana River Drainage. The expectation that prehistoric stone tool procurement optimization is represented by an abundance of low cost material and a lack of high cost material at sites in the region is tested using calculations generated in ArcGIS of the cost to walk away from raw material sources. When sites with a relevant sample size fail to meet these expectations, differences in the artifacts of each material and individual sites assemblages are examined to explain the lack of patterning between material amount and cost. I will begin this section by discussing the origins of the data set used in the project. Next, I will overview my data organization and lithic classification. Sections describing my analysis by means of GIS and SPSS statistics program will conclude this chapter.

Data Sets

The data examined in this thesis is a compilation of two datasets. One dataset is made up of a large sample of all the rhyolite lithic materials that occur in the assemblages of each archaeological site in the Tanana River Drainage. The other dataset is made up of all the obsidian lithic materials that occur in the assemblages of each archaeological site in the Tanana River Drainage. The archaeologists that excavated the sites in the Tanana River Drainage contributed all the information about the artifacts to the datasets. The information most importantly includes, the raw material type (obsidian or rhyolite) site number, geographic location, the lithic classification, maximum dimension, weight, cortex absence/presence and the geochemical source group/source location.

The rhyolite dataset was compiled by Coffman and Rasic (2015). The majority of their Tanana River Drainage dataset came from artifacts housed at the University of Alaska Museum of the North and several active field research projects conducted in the region. I included eighty-three Tanana River Drainage sites from their dataset. Coffman and Rasic (2015) selected a sample of 30 rhyolite artifacts from each site containing rhyolite in Interior, Alaska. When site components included more than 30 rhyolite artifacts, the first 30 artifacts in the collection were randomly selected for analysis. When a site contained less than 30 rhyolite artifacts all the rhyolite artifacts in the assemblage were included in the dataset. The total rhyolite dataset consists of 518 artifacts. Coffman and Rasic (2015) used pXRF analysis to measure the key elements (ppm of K, Mn, Fe, Zn, Ga, Th, Rb, Sr, Y, Zr, and Nb) within each rhyolite artifact and then identified statistically similar geochemical groups of rhyolite. Each geochemical group is expected to correspond to one source of rhyolite on the landscape. In addition to the geochemical analysis, Coffman and Rasic recorded the qualitative and quantitative properties of each artifact in the dataset. These properties include the lithic classification (microblade, microblade core, projectile point, utilized flake etc.), weight, maximum dimension, etc. The dates that were available for some of the artifacts, based on radiocarbon dating at certain sites, ranged from the late Pleistocene through late Prehistoric period (ca. 200 BP) (Coffman and Rasic 2015).

The obsidian dataset was provided by the University of Alaska Museum of the North. It consists of a selection of all the obsidian artifacts at each site in the Tanana River Drainage taken from the Alaskan Archaeological Obsidian Database (AAOD) as of 2010. The AAOD was formed by the cooperation of the Smithsonian's Museum Conservation Institute, the National Park Service, the UA Museum of the North, and numerous other researchers, and is a

compilation of all the information available relating to obsidian artifacts in the circumpolar region. The AAOD includes over three thousand artifacts from over 360 sites in Alaska, Yukon, British Columbia, and NE Asia; 1,256 obsidian artifacts from 87 Tanana River Drainage sites make up the assemblage analyzed here. The obsidian dataset is structured similarly to the rhyolite dataset with information on the geochemical composition of each artifact, as well as lithic classification, site number, weight, etc. Both datasets have the temporal span of archaeological sites ranging from the Late Pleistocene through the historic period.

Limitations of the Data Sets

The limitations of these data sets are characteristic of extensive regional compilations of information and are a result of the data being compiled by multiple archaeologists using data from sites excavated at different times by different archaeologists. The information that is insufficient in this dataset and would improve this analysis includes dates of the artifact assemblages, complete information on all the site assemblages containing rhyolite rather than a sample, and uniform lithic classification scheme at the most detailed level.

There are a number of assumptions that have taken place in this analysis due to the extent and lack of uniformity of the dataset. One problem with the dataset was that several sites contained artifacts that were listed as “undetermined” or did not have a weight value. For the purpose of this study the “undetermined” artifacts were not included. In instances when weight was not provided for the artifacts, which only happened twice, the maximum dimension (which is proportional to the weight) was used to calculate the percentage of material at the sites. Another problem with the dataset is that most of the sites in the Tanana Rive Drainage did not

contain large enough numbers of artifacts and/or heavy enough assemblages to warrant being used in this analysis because the sample size was too small to be relevant for comparing the use of the igneous raw materials. Further, sites that were outside of the Tanana River Drainage but still between the Tanana and Batza Téna were not included because Batza Téna itself is not in the Tanana River Drainage. The inclusion of these sites could reveal a relationship between a high amount Batza Téna material and low cost of acquisition since more sites closer to the Batza Téna source are noted to have Batza Téna material (Clark 1995).

The most glaring problem with the data used was the lack of dates associated with the artifacts from each site. There were several general time periods mentioned with artifacts in the original AAOD and rhyolite dataset, such as Late Pleistocene, Early Holocene, and Early Historic period, but there was not enough of this information to apply the time dimension to this study. This could be considered extremely problematic as archaeologists have noted that a time dimension is critical for understanding site function and subsistence patterns (logistical or residential mobility), as these strategies are thought to have shifted over time (Potter 2008). Site function was included in the interpretation of the data, while this could be discounted due to lack of dates, it valuable as a preliminary analysis since most of the sites in the mountains around Rhyolite A and in the Tanana Valley have assemblages without much variation in tool type.

Data Organization

The two datasets were merged; information on several attributes of each rhyolite and obsidian artifact (site number, geographic location, lithic classification, maximum dimension, weight, and source group) was combined into one Excel spreadsheet. The obsidian data was

made uniform by reclassifying the artifacts into more general lithic classification categories that best matched the detailed classification employed by Coffman and Rasic for the rhyolite analysis. The lithic classification categories are described in the following section. Once the two datasets were combined and their fields compatible, the total number of artifacts of each material at each site was used to calculate the percentage of obsidian and rhyolite (by count) for each site. Then, the total amount (by number of artifacts) was used to calculate the percentage of Batza Téna obsidian, Wiki Peak obsidian, other obsidian, rhyolite A, and other rhyolite was calculated for each site. Next, these same calculations were performed again using the weight values of the artifacts. It is important to consider both weight and counts when analyzing lithic assemblages (Andrefsky 2009: 80; MacDonald 2009). For instance, archaeologists would like to distinguish sites with a single, heavy artifact from sites with a large number of lighter artifacts. Similarly, we would like to be able to distinguish sites with equivalent counts, but different artifacts types, such as a site consisting of 20 cores versus 20 pieces of debitage. In this instance the weight of the assemblages would be important 20 cores are likely to outweigh 20 pieces of debitage. Since this project focuses on the energetic costs of transport, weight may be most important for understanding how material was distributed around a raw material source. Finally, the percentage of the total weight of each lithic classification (formalized, expedient, microblade technology, debitage, and undetermined) was calculated for every raw material category (Batza Téna, Wiki Peak, other obsidian, Rhyolite A, and other Rhyolite) for each site.

GIS Analysis ArcMap 10.x

Spatial approaches have proven to be useful tools for examining hunter-gatherer mobility and lithic technological organization (Andrefsky 2009). A common technique used to measure the cost of lithic transport and raw material choice is comparing the properties of lithic assemblages to the distance to their sources (Ricklis and Cox 1993; Newman 1994). For example, the distance between a toolstone source, residential site, and location an artifact was discarded has been demonstrated as a key factor in tool conservation (Andrefsky 2008). However, when considering how humans move across the landscape there are a number of factors in addition to distance to take into account, such as terrain (swamp, desert, rocks) or barriers (unfrozen bodies of water, steep mountains). When creating a mathematical surface to best represent the energy associated with crossing the landscape it is possible to account for these costly, “friction,” factors.

A friction surface is a model of the landscape that mathematically adds resistance to the land traveled. An isotropic friction surface model only uses distance as the resistance or friction factor therefore the cost of traveling away from one location is uniform in every direction. For instance, the cost of travelling farther from a source is higher than traveling to a location nearby no matter what direction one goes. Anisotropic friction surface models can combine multiple “friction” factors, such as slope and distance. Anisotropic models are better for understanding human movement because it takes into account more costly variables and the cost to travel in every direction from a starting point is not uniform (Kantner 2004). Figure 3.1 shows the elevation model of the Tanana River Drainage landscape. This model can be compared to Figure

3.2, which shows the anisotropic cost model of the same area. It is clear by comparing these two surfaces that the anisotropic model takes into account both distance and slope based on elevation.

The affects of slope on energy costs of movement have been carefully studied (Tobler 1993). While it may seem important to consider the direction of movement (uphill vs. downhill) Tobler 1993 found that the cost associated with hiking uphill mirrors the cost of breaking going downhill. This is significant to recognize when studying the transport of raw materials from a source because it limits the uncontrollable variable associated with the direction people could have traveled to discard the tool. However, this study focuses on the energy it takes to transport raw material away from a source.

Second, the ratio between cost and slope is not one to one. Whitley and Hicks (2003) points out that the relationship is better modeled as exponential; that is, at low slopes slight increases in slope have minimal effects on cost, but at much higher slopes, each increment of slope increase has a much greater cost to the traveller. For instance, at some point slopes become so steep as to require hand-over-hand climbing and ultimately may be not traversable. Tobler's Hiking Function (Tobler 1993,) is an anisotropic model that based on an exponential relationship between slope and cost and thus provides a more realistic friction surface for cost calculations. Additionally it was derived from empirical data from real-life contexts and has been recreated empirically in lab and other real-life settings (Kantner 2004: 333). It has been used by many archaeologists to model the cost of walking in a variety of world regions (Whitely and Hicks 2003).

The algorithm derived for Microsoft Excel that calculates the speed to traverse terrain in terms of slope steepness was used to create a vertical factor table. This algorithm from Tobler's

Hiking Function calculates that humans could walk on a zero degree slope at 5.037 km/hr (Tripcevich 2009). The vertical factor table was used in ArcMap to calculate the time it would take to walk across the landscape in any direction away from each source separately (cf. Appendix A for complete details). The results of the calculations of time of travel away from the sources by ArcMap should be in minutes. However, the values are relative in terms of time and not absolute. The values produced by ArcMap are overestimated in terms of absolute time and therefore are not accurate representations of the time it would take for a human to actually walk across the landscape. More importantly, the values are correct in relation to one another, therefore the value given to the time it takes to travel to one site is correct in comparison to others on the landscape.

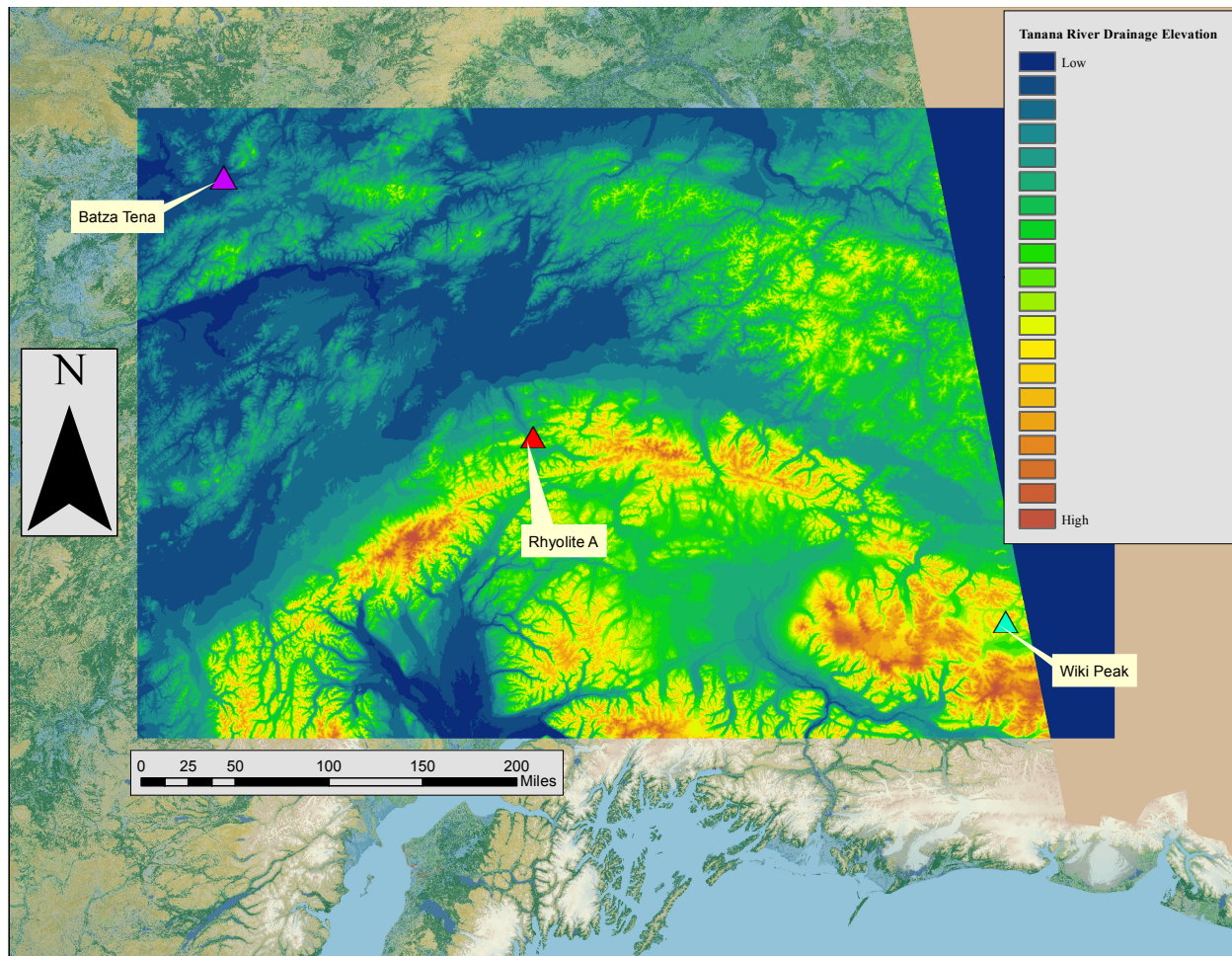


Figure 3.1 Shows the elevation landscape of the Tanana River Drainage. This map layer is the Digital Elevation Model in ArcMap.

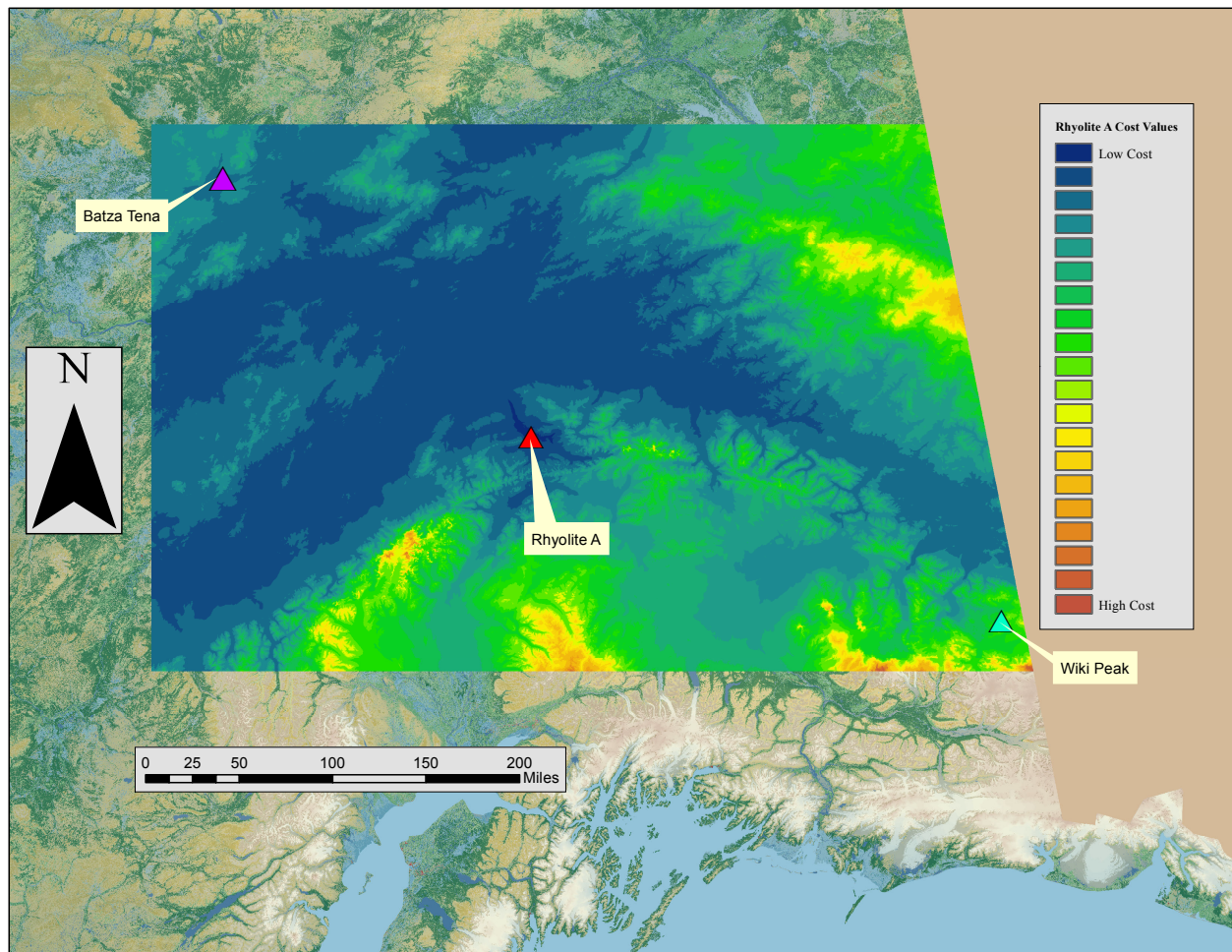


Figure 3.2 Shows the anisotropic cost model calculated based on distance from the Rhyolite A source and slope. Slope was calculated from the digital elevation model.

Lithic Classification

The lithic classification categories used in this project are meant to be basic and primarily focused on archaeologists' assessment of the general patterns of use of these tools. There are two main purposes for creating these categories and they will play an important roll in the investigation of secondary hypotheses in the series of analysis of this project. Primarily, it is to make the lithic classifications that were already given to the artifacts by the researchers uniform in order to combine the obsidian and rhyolite datasets. The original datasets included a specific lithic classification to each artifact, such as secondary decort flake or bifacial pressure flake (cf. Appendix B). In future analysis it may be important to make these specific distinctions but for the purpose of this project these two lithic types fall under the broader category of debitage. Secondly, this project examines the relationship of the amount of obsidian and rhyolite toolstone in the Tanana River Drainage. In order to explain the relationship it is necessary to understand how the attributes of the toolstone (flaking properties) may affect the tool type. Different tool types may tend to be made out of a particular material. The lithic classification categories allow archaeologists to look for these patterns with a larger sample size than with specific tool-by-tool analysis. The following categories are my interpretation of the classification scheme for these lithics and could be interpreted differently by other archaeologists. The dataset consisted of extremely variable terminology relating to the classification of lithics and because of this I made assumptions about taxonomy that would otherwise necessitate examining individual artifacts to better conclude their function.

The categories consist of formalized artifacts, expedient artifacts, microblade technology, and debitage. Debitage includes all forms of flakes (interior flake, bifacial pressure flake,

nondiagnostic flake, etc.) except bipolar flakes, linear flakes, utilized flakes, retouched flakes, and flake tools. Debitage can be referred to as any lithic debris that is discarded at an archaeological site, however for the purpose of this project debitage refers to lithic debris that was produced during the reduction of a formalized or expedient tool and does not show evidence of being used itself.

Expedient artifacts include certain forms of flakes that are not considered debitage because they could be utilized for purposes beyond being the initial result of forming a formalized tool. Expedient tools take minimal time and effort to form and therefore are used in situations where the need for formalized tools is unanticipated or unnecessary. They are often manufactured and employed in situations where the task at hand is predictable because one's effort is focus on an immediate, specific task, therefore the tool design is specific and for short term use (Mijares 2001, Nelson 1991: 64, Binford 1983: 283). Expedient artifacts include bipolar flakes, linear flakes, utilized flakes, retouched flakes, and flake tools. Often utilized flakes and retouched flakes form a unifacial technology. This form of unifacial technology is expedient, however artifacts that were classified as uniface by the original analyst are formalized artifacts.

Formalized artifacts include bifaces, uniface, blades, all forms of projectile points, cores, and an adze. These are all artifacts that take more time and skill to form than expedient tools. They are made for specific purposes in which expedient tools are less likely to function successfully. Time and effort is invested into a formalized tool in order to increase its life and ability to reliably perform the tasks for which it is needed. For example a core is formalized because it must be carefully shaped by removing the cortex of the stone to be able to maximize the flakes it can produce which will be made into tools. Blades used for cutting are formalized

because they are tools that take a considerable amount of time to make with a sharp edge, they are maintained and resharpened, and carried for a long time.

Microblade technology includes microblades, microblade cores and associated core debitage (core tablets, core debris etc.), burins, and burin spalls. Microblade technology has attributes of both an expedient and formalized technology, while many microblades can be flaked from one microcore, the microcores require sophisticated preparation (Clark 2001:64; Andrefsky 2005:144-145). These artifacts are given a category of their own because microblade technology appeared in the upper Paleolithic of central Asia and spread to China and Northern Japan around 32,000 B.P. (Hayashi 1968). It then spread into the Russian Far East occurring around 19,000 B.P. and eventually to the New World (Goebel 1999). Microblade technology was first seen in eastern Beringia at Swan Point approximately 14,300 years ago and lasts until 1,000 years ago if not later in some regions of Alaska and the Northwest Coast (Smith 2012; Potter 2008b) It has been well studied since it has such a distinct form and there is no true consensus of what function it served. Specialized knapping skills are required in order to produce the razor-like blades approximately 4 to 8 mm in wide and 2 to 3 cm long from the cores. It is widely believed that the microblades were meant to be inset into organic materials and served as weapons (Potter 2008b; Clark 2001).

Case studies were employed to further test the preliminary hypothesis based on raw material amount and cost. Two of these case studies looked at unifacial and bifacial technology. These more specific categories warrant an explanation. A uniface is a tool that has only been modified on one surface (Andrefsky 2005:262). A common use for this technology is scraping activities, such as scraping an animal hide. In this study unifacial technology consists of artifacts

originally classified as unifacial tools, gravers, utilized flakes, and retouched flakes. Whether or not a utilized flake and retouched flake are unifacial could be argued, however in this dataset Coffman and Rasic (2015) further classified these two types of artifacts as unifacial tools. They did not make this distinction with flake tools. Therefore, flake tools are not included as unifacial technology.

A biface is understood as a tool that has been modified so that two surfaces form one edge (Andrefsky 2005:253). These tools are often useful for piercing. In this study bifacial technology consists of artifacts originally classified as bifaces, biface knives, all forms of projectile points, Chindadn points, blades, blade tools, biface tips, biface preforms, biface fragments, biface mid-sections, and an adze.

Statistics Analysis Methods

The expectation of this project is that there should be a higher proportion of material at a site with a lower cost value from the material's source. Each artifact was associated with a site number. The number and weight of the artifacts of each material at each site was calculated. The percent of each material by weight could be calculated for each site. Each site was given a cost value from each raw material source (Batza Téna obsidian, Wiki Peak obsidian, and Rhyolite A). The percent of the raw material at any site could be studied in terms of the cost to its source. To test the expectation 35 sites were chosen as sufficient sample sizes to be meaningful to the analyses. To be considered relevant the sites must consist of either 10 or more artifacts (by count) or 20 or more grams of material. Therefore, sites were not excluded that had one heavy artifact, nor were they excluded if they had 10 or more very light artifacts. Simple scatterplots

were generated using SPSS statistics software to test the relationship between the percent of a raw material (Y-axis) and the cost of obtaining that raw material (X-axis).

Pearson's two-tailed test of correlation was employed to determine the strength of correlation between the two variables, percent of raw material and cost; cf. Tables 4.1, 4.2, and 4.3. The Pearson Correlation variable is the correlation coefficient, which determines the strength of the relationship between the two variables. The closer this number is to 1, the stronger the correlation is. Whether this number is positive or negative determine the direction (positive or negative) linear relationship. The Sig. (2-tailed) variable determines if there is a statistically significant correlation between the two variables. If the value of this variable is greater than 0.05 then there is no statistically significant relationship between the two variables (Tables 4.1, 4.2, and 4.3).

Results

Human Behavioral Ecology and Optimal Foraging Theory, predict that prehistoric hunter-gatherers acted to optimize energy expenditure, and therefore they are expected to have favored raw materials with the lowest cost of acquisition. The expectations formed from this dataset are as follows: if humans favored raw materials with the lowest cost of acquisition, then there should be a negative linear relationship between percent raw material at a site and the cost value given to the site. For instance, a site that has a low cost distance from Batza Téna should be made up of a high percentage of Batza Téna material, and if a site has a high cost distance from Batza Téna then it should have a lower percentage of Batza Téna material. The same pattern should also be reflected by Rhyolite A material and Wiki Peak material. In order to test the preliminary hypothesis based on OFT I assume the goal of the prehistoric hunter-gatherers was to maximize foraging efficiency, their energy currency is time, and the constraints to performing their foraging activities are distance to travel and steepness of the terrain, finally the option that people had was to use toolstone that was the least costly to acquire. Although there are other unknown sources of rhyolite and obsidian in the Tanana River drainage, sites used in the analysis were chosen based on sample size, which excluded sites that were dominated by these other materials. Further, sites from the rhyolite data set were excluded if they had more than 30 artifacts because artifacts were sampled from sites that contained more than 30 artifacts. Finally, sites that had 10 or more artifacts or 20 or more grams of raw material were included in the cost analysis in order to control for biases associated with overly small assemblages.

The results that ensue are laid out in a series of analyses that develop the basic understanding of the dataset, test the original hypothesis, and then further tests hypotheses to

explain why the original hypothesis failed. Each single analysis in the series played a critical roll in developing subsequent questions, which ultimately led to a conclusion about prehistoric human behavior. The first two sections *Raw Material Diversity* and *Overall Tool Classification Breakdown by Material* offer a basic understanding of the dataset that will be important points of reference for understanding the subsequent, more in depth, analyses. The following section, *Relationship between Material Weight and Material Cost*, is the results of the analysis that tests the preliminary hypothesis. A case study was developed after the first hypothesis was not met, in order to test the same hypothesis but with a more specific dataset, which included cortex absence and presence. The results still did not meet the hypothesis. The next three sections, *Sites on the Cost Landscape*, *Tool Classification Breakdown of Selected Sites*, and *Sites of Interest in the Tanana River Drainage*, investigate the lack of relationship between material amount and material cost by understanding the distribution of the stone tool assemblages on the landscape and looking for patterns in the artifact types. The section *Rhyolite and Obsidian Sites by Physical Location (Mountain Ridges vs Tanana River Valley)*, shows the difference in the stone tool technology used at sites at different locations on the landscape. Finally, the last two sections *Weights of Obsidian Tools compared to Rhyolite tools* and *Formalized Tool Weight and Maximum Dimension Comparison* examine the difference in size between rhyolite tools and obsidian tools, which will also support conclusions about prehistoric human mobility.

Raw Material Diversity

The number of different raw materials present in a site assemblage may increase as the number of individual artifacts increases. If there are more individual artifacts, the probability that

different raw materials will be present at the site increases. For the purpose of this study sites with ten or more artifacts, or 20 or more grams of raw material were chosen to eliminate the sites that may lack raw material diversity due to a small sample size. Figure 4.1 shows the percent based on weight of materials at each site, as the number of artifacts increases. Figure 4.2 shows the percent based on weight of materials at each site, as the total weight of each site assemblage increases. Both of these charts represent the 35 sites that contain at least 10 artifacts or 20 grams of material. The graphs depict no significant pattern showing that raw material diversity increases linearly with greater sample sizes. However, the first three sites containing up to two artifacts obviously only contain one material, while the site with the greatest number of artifacts has the greatest diversity (Figure 4.1). Site function could account for the lack of consistency between the number of artifacts and the number of different raw materials at sites with between three and 100 artifacts. For instance, a site with ten flakes of one material could have been a location where one stone tool was manufactured but then transported away. Yet, the number of artifacts at the site may be the better indicator of toolstone diversity because a higher number represents a higher number of distinct artifacts, aside from the case where high quantities of debitage may only represent one tool. Conversely, a high weight could very well indicate just one heavy artifact. Figure 4.1, which shows the toolstone diversity based on increasing assemblage weight is important to compare to Figure 4.1, based on the number of artifacts in order to visualize the differences between the two variables. Since sites with over 10 artifacts or over 20 grams of material were considered for this study, understanding the differences in these variables for the entire assemblage reveal why both are chosen. They were chosen to ensure a

valuable site is not excluded because its assemblage light, even though it may have 10 or more artifacts of different materials.

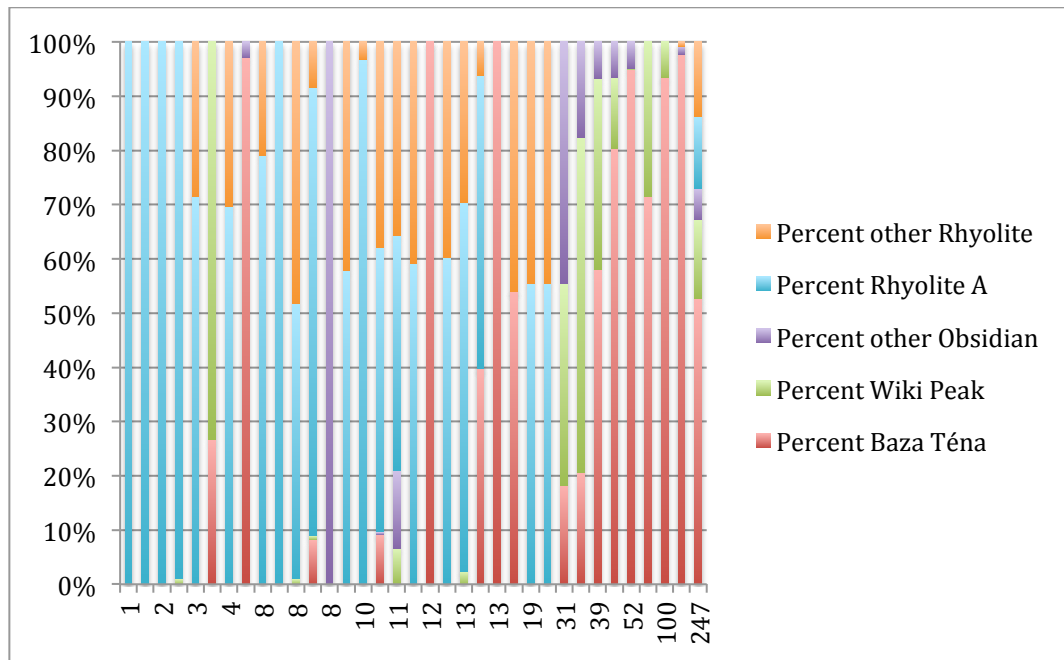


Figure 4.1 Shows the distribution of different types of raw material at the 35 sites in this study. The Y axis shows the percent of materials at each site calculated by weight (g). The X axis shows the number of artifacts in each site assemblage in increasing order.

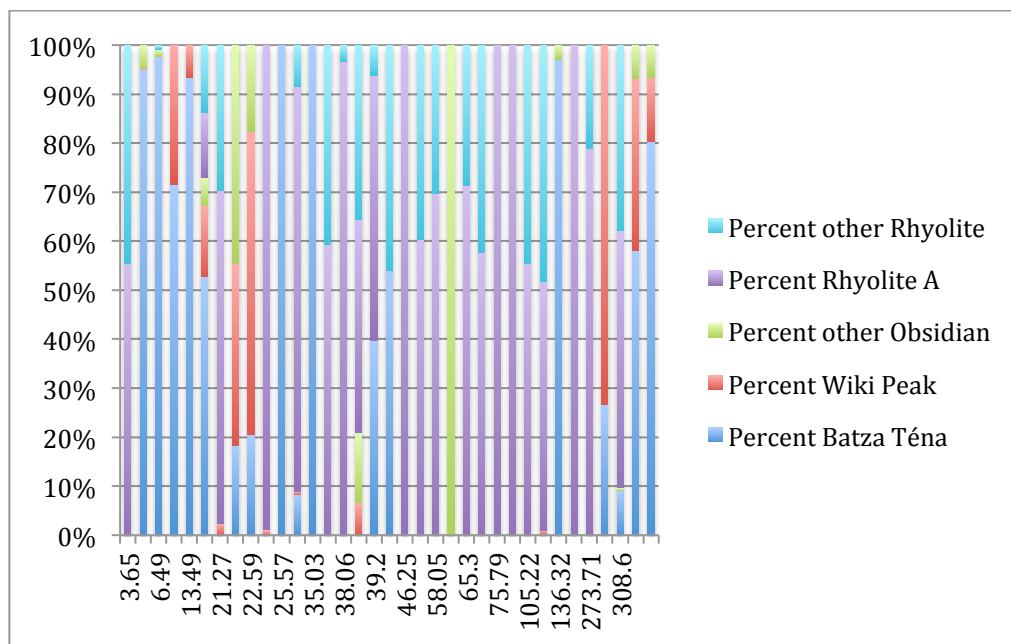


Figure 4.2 Shows the distribution of different types of raw materials at the 35 sites in this study. The Y axis shows the percent of material at each site calculated by weight (g). The X axis shows the cumulative weights of the site assemblages in increasing order.

Overall Tool Classification Breakdown by Material

Figures 4.3 through 4.6 represent the percent of each tool type for all the obsidian artifacts in the dataset and all the rhyolite artifacts in the dataset. The percent breakdown by weight and count were both included here to show, as I did above, how weight and the number of artifacts differ. These figures will be useful for comparison with results that follow in the analysis. For instance, the percent of material at each of the 35 sites used in the cost analysis is based on the material weights. Also the tool classification breakdown of materials at the selected sites is based on artifact weights. Therefore, Figure 4.3 and 4.5 will be more important to use as points of reference when looking for deviations from the overall pattern revealed in the subsequent charts.

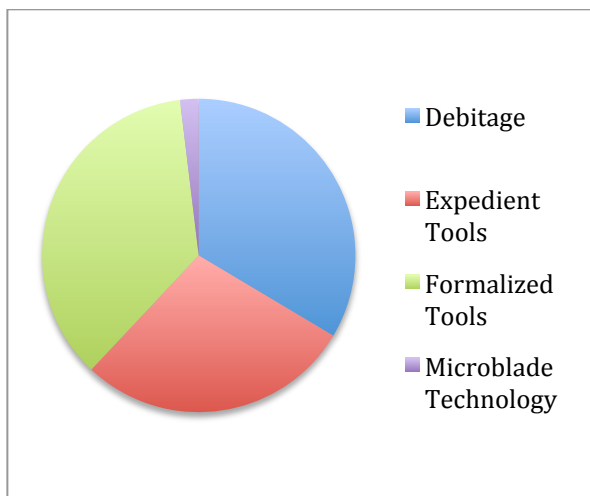


Figure 4.3 Percent of different tool types made of obsidian based on artifact weights for all the obsidian in the dataset.

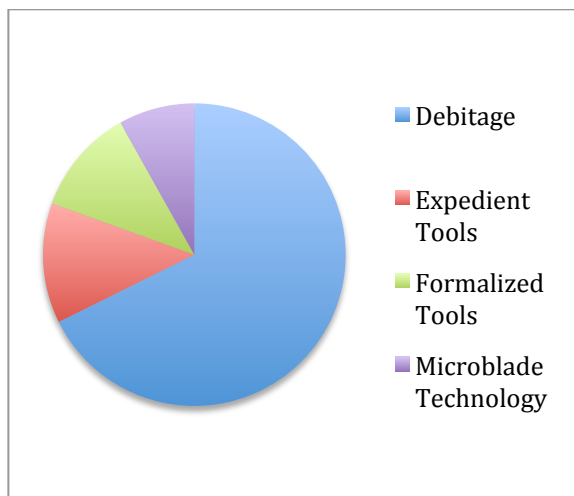


Figure 4.4 Percent of different tool types made of obsidian based on artifact count for all the obsidian in the dataset.

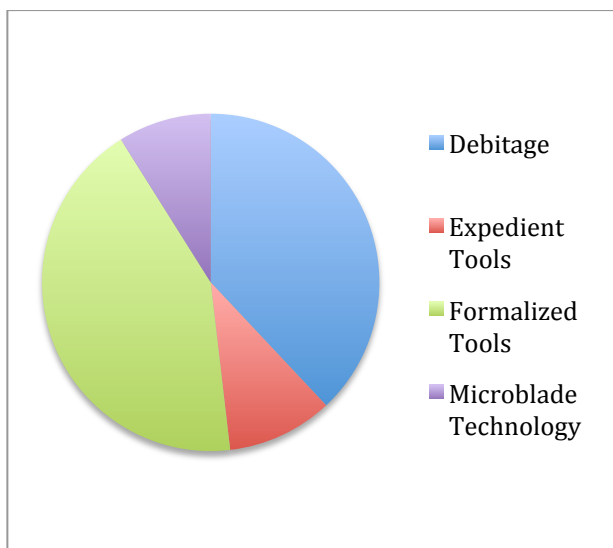


Figure 4.5 Percent of different tool types made of rhyolite based on artifact weights for all the rhyolite in the dataset.

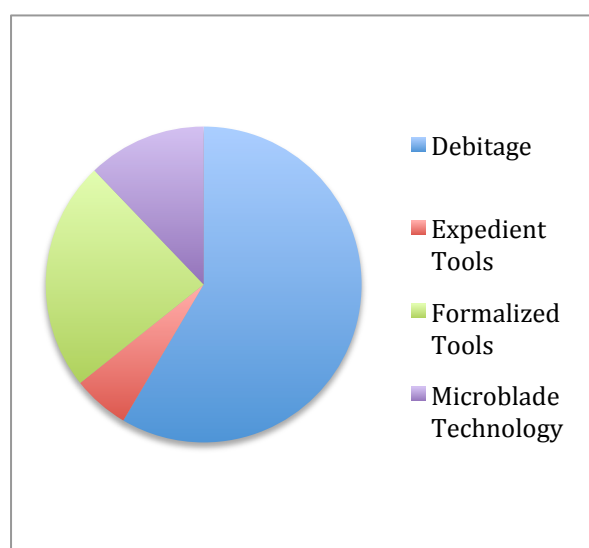


Figure 4.6 Percent of different tool types made of rhyolite based on artifact count for all the rhyolite in the dataset.

Relationship between Material Weight and Material Cost

The cost of raw material acquisition is represented by the energy it takes to travel from the location of the raw material on the landscape to its place of ultimate deposition. Tobler's Hiking Function calculates energy in terms of time. The results of ArcMap's calculations based on Tobler's Hiking Function are in minutes, however, recall that these results in minutes are relative to one another and not the actual time it takes to walk across the landscape. ArcMap calculates the least costly route of travel across the landscape and thus assumes a direct route between the source and the discarded artifact. This is just one line of evidence in addressing raw material procurement and does not address artifacts' travel to other locations prior to discarding them at the site. Due to the ways Tobler's Hiking Function calculates values, these output values are a minimum estimate of the cost of transporting artifacts across the landscape. For instance, tools such as well-used bifaces were likely carried over a much more circuitous route than the least cost path calculated by Tobler's Hiking Function.

Three raw material sources were chosen to test the relationship between material cost and amount (weight) of the material at sites. Weight was chosen as the variable to test this hypothesis because it is directly related to energy efficiency as assumed by Optimal Foraging Theory. The assumption is that heavier objects require more energy to transport and therefore humans would transport the heaviest objects the least distance.

The three raw material sources are Batza Téna an obsidian source in northern Alaska, Wiki Peak an obsidian source in the southeast, and group A rhyolite thought to be located in central Alaska. Raw material percentages at the sites were calculated based weights of each artifact. The percent of each material at these sites was graphed on a scatterplot according to the

sites' cost value associated with traveling away from each respective source (Figures 4.7, 4.8, 4.9).

Recall, the significance of the relationship between raw material percent and cost was tested using SPSS statistics Pearson's double tailed test of correlation (Tables 4.1, 4.2, and 4.3). The closer the correlation coefficient is to 1, the stronger the correlation is. If the correlation coefficient is positive or negative determines the direction of the linear relationship. If the value the Sig. (2-tailed) variable is greater than 0.05 then there is no statistically significant relationship between the two variables.

According to the scatterplots and Pearson's double tailed tests of correlation, there is no statistically significant correlation confirming a linear relationship between cost and raw material amount for Batza Téna and group A rhyolite material, and there is a weak significant correlation between the two variables for Wiki Peak material. The correlation coefficient for the Batza Téna test is -0.295, for the Wiki Peak test it is -0.422, and for the group A rhyolite test it is -0.045 (Tables 6.1, 6.2, and 6.3). The correlation coefficient in each of these tests is negative, suggesting that if there were a significant linear relationship between material amount and cost it would be negative. This direction of the relationship is expected, however correlation coefficient is not close to one in all three tests, which means that the relationship between material amount and cost is very weak. The only significance value from these three tests that is less than 0.05 is from the Wiki Peak test with a value of 0.012. Though Wiki Peak obsidian is the least represented of the three materials in the site assemblages, it is the only material that satisfies the expectations of the hypothesis. It is possible that out of the 35 sites analyzed the large number

assemblages containing 0% Wiki Peak material (n=20) is influencing the significance of Pearson's double tailed test.

Despite the weakness of the correlation between raw material amount and cost, the scatterplots reveal that sites cluster in certain ranges of cost distance from their sources. Batza Téna obsidian occurs in site assemblages that have a cost distance between 3,783,770 minutes and 6,780,815 minutes from the Batza Téna source (Figure 4.7). Wiki Peak obsidian occurs in site assemblages that have a cost distance between 9,144,066 minutes and 14,884,907 minutes from the Wiki Peak source (Figure 4.8). Group A rhyolite material occurs in site assemblages that have a cost distance between 5,112,057 minutes and 12,363,277 minutes from the Rhyolite A source (Figure. 4.9). People traveled at less cost from Batza Téna and incurred the greatest cost to travel from Wiki Peak. As expected, in the case of Batza Téna material and Wiki Peak material sites with the highest cost from these sources have 0% of each respective material. However, there are a number of sites that have very low costs from these sources and also contain 0% of these materials in these site assemblages. Conversely, the highest cost site from the Rhyolite A source contains 100% group A rhyolite material but there are also sites with low costs from rhyolite A that contain 0% group A rhyolite material.

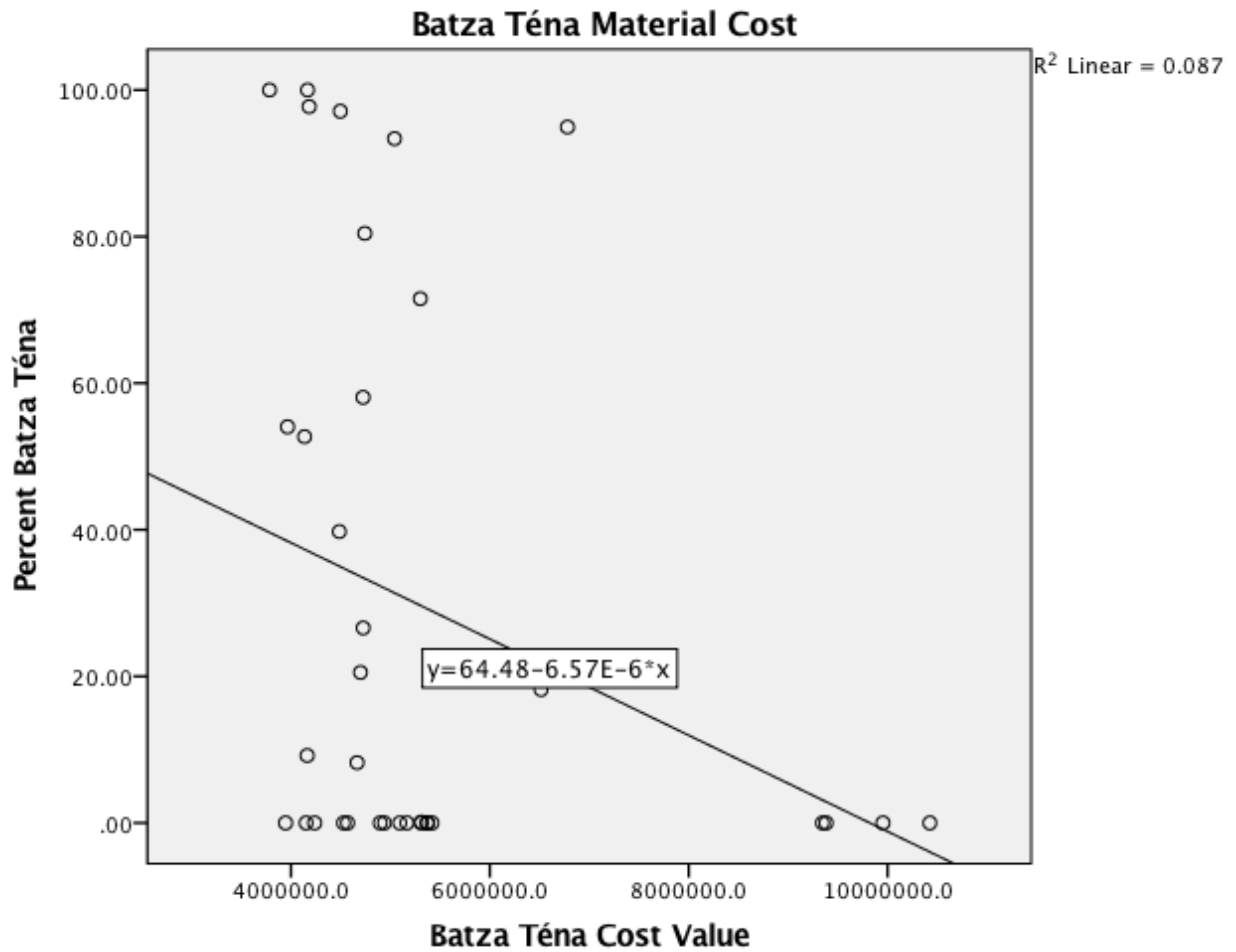


Figure 4.7 Shows the lack of correlation between raw material amount and the cost of the material. The Y axis shows the percent of Batza Téna material at each site in terms of weight (g). The X axis shows the cost (time) to travel from Batza Téna to each site where the artifacts were ultimately discarded.

Table 4.1 Shows the significance of the correlation between the percent of Batza Téna material at each site and the cost of transporting the material from Batza Téna.

Correlations

		Percent Batza Téna	Batza Téna Cost Value
Percent Batza Téna	Pearson Correlation	1	-.295
	Sig. (2-tailed)		.085
	N	35	35
Batza Téna Cost Value	Pearson Correlation	-.295	1
	Sig. (2-tailed)	.085	
	N	35	35

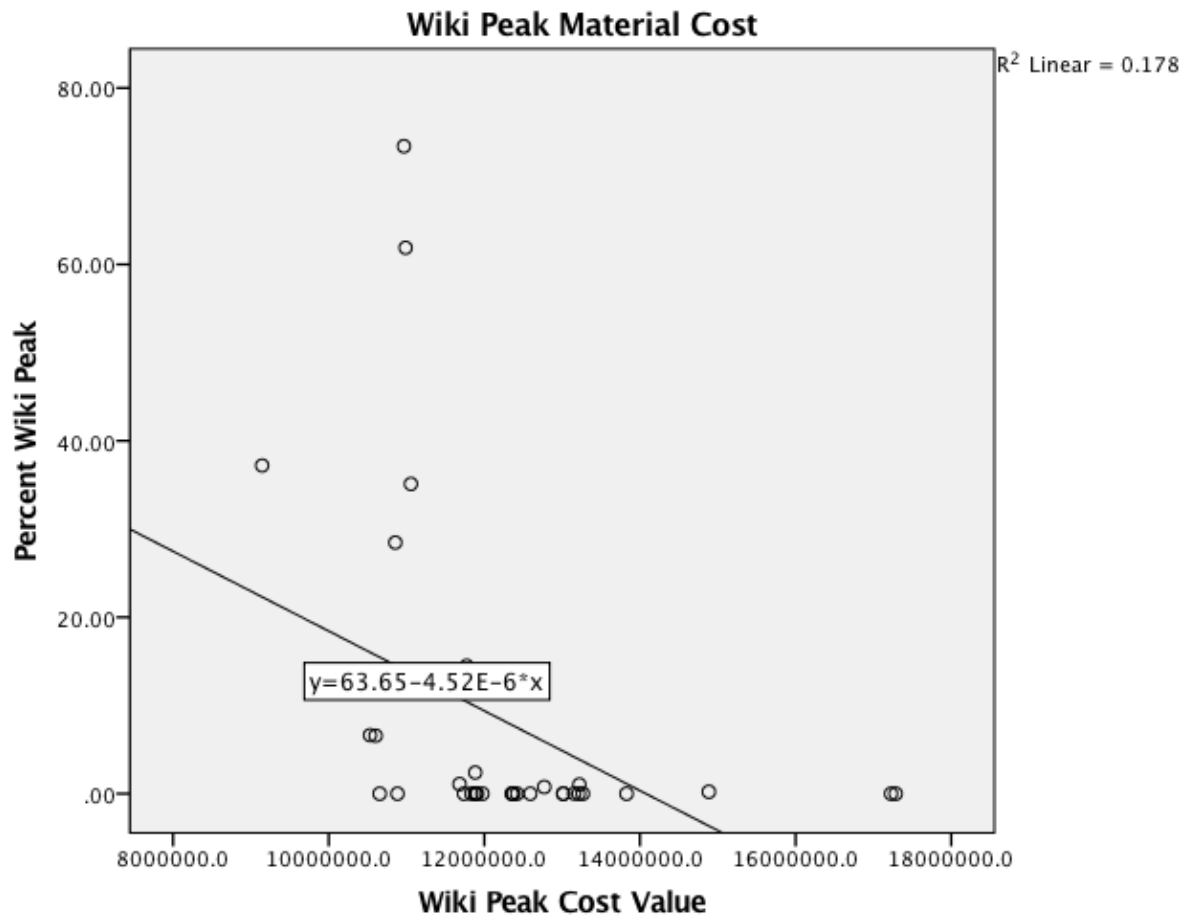


Figure 4.8 Shows the lack of correlation between raw material amount and the cost of the material. The Y axis shows the percent of Wiki Peak material at each site in terms of weight (g). The X axis shows the cost (time) to travel from Wiki Peak to each site where the artifacts were ultimately discarded.

Table 4.2 Shows the significance of the correlation between the percent of Wiki Peak material at each site and the cost of transporting the material from Wiki Peak.

Correlations

		Percent Wiki Peak	Wiki Peak Cost Value
Percent Wiki Peak	Pearson Correlation	1	-.422*
	Sig. (2-tailed)		.012
	N	35	35
Wiki Peak Cost Value	Pearson Correlation	-.422*	1
	Sig. (2-tailed)	.012	
	N	35	35

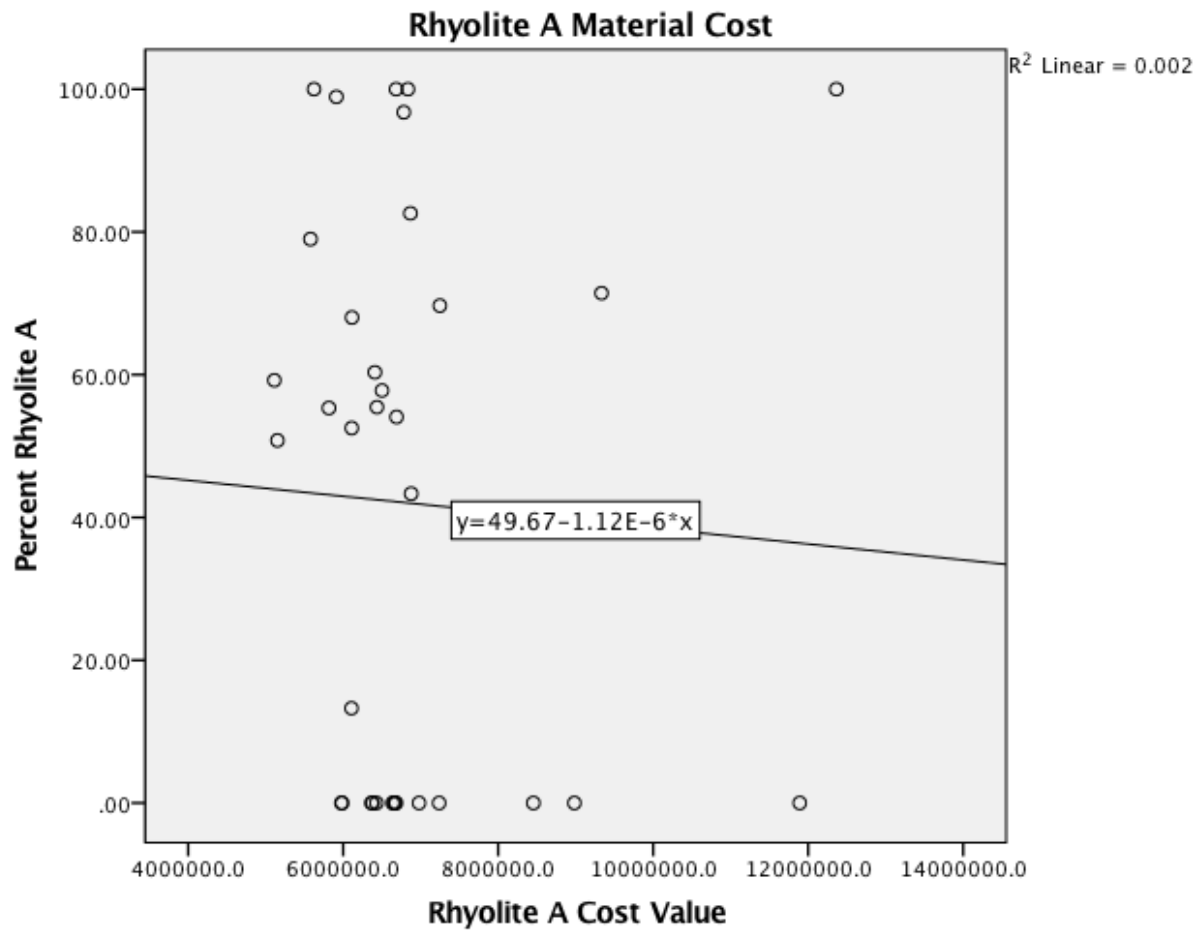


Figure 4.9 Shows the lack of correlation between raw material amount and the cost of the material. The Y axis shows the percent of group A rhyolite material at each site in terms of weight (g). The X axis shows the cost (time) to travel from the estimated Rhyolite A source to each site where the artifacts were ultimately discarded.

Table 4.3 Shows the significance of the correlation between the percent of group A rhyolite material at each site and the cost of transporting the material from the estimated Rhyolite A source.

Correlations

		Percent Rhyolite A	Rhyolite A Cost Value
Percent Rhyolite A	Pearson Correlation	1	-.045
	Sig. (2-tailed)		.797
	N	35	35
Rhyolite A Cost Value	Pearson Correlation	-.045	1
	Sig. (2-tailed)	.797	
	N	35	35

Case Studies

Three case studies using a subset of the data were examined in order to see if there were inconsistencies with the outcome of comparing raw material amount by weight to the material cost of all the artifacts from the sites that were chosen to best represent the whole dataset. The subgroups of data that were chosen to retest this pattern were unifacial technology, bifacial technology, and the absence/presence of cortex. Cortex is the weathered outside of stone with a different color or texture than the interior of the stone and is often removed in the manufacture of tools.

Unifacial and bifacial technology were chosen because out of the entire rhyolite and obsidian datasets they had the largest sample sizes. The results of these analyses did not resolve the lack of relationship between raw material amount and transport cost. Therefore, the analyses are shown in Appendix C. The cortex absence and presence information from the original

datasets is not extensive but since this quality of toolstone is related to efficiency it is a relevant form of analysis to test the hypothesis.

Cortex must initially be removed from a stone to manufacture tools or form a core (Andrefsky 2005:103-104). It is the least useful part of the stone to transport. It is expected that if prehistoric humans were acting efficiently, they would not transport the cortex of raw material long distances. Therefore, artifacts with cortex present should appear at low costs from the raw material source, while artifacts without cortex should appear at higher costs. The analysis based on the cortex absence/presence data available did not reflect this pattern strongly. Sites that contained artifacts with cortex information were included in this analysis (n=84). The percent of the assemblage with cortex absent and cortex present was calculated independently for each material (Rhyolite A, Batza Téna, and Wiki Peak).

Cortex Case Study

The amount of cortex absent or present was calculated by adding the number of artifacts of each assemblage that were described in the original datasets as having cortex absent or present. Then the percent cortex absent and present was calculated for each raw material. Table 4.4, 4.5, 4.6 show the raw material cost values in relative minutes and in increasing order. The cost values are associated with a site assemblage on the landscape. The number of artifacts in the assemblage with cortex absent or present is accompanied in the table by the percent of the assemblage with these qualities. It should be expected that the percentages of cortex present should decrease as the cost values increase. In order to view the distribution of sites assemblages

that contain artifacts with and without cortex Figures 4.10, 4.11, and 4.12 are geographical representations of Tables 4.4 through 4.6

Rhyolite A material does not consistently reflect this pattern though the greatest number of artifacts with cortex (n=15) occur at the least costly location from the source. However, in general there is a very small number of group A rhyolite artifacts with cortex. Although most of the sites with group A rhyolite cortex only have a sample size of one or two artifacts, site HEA-0001 has the seventh highest cost from Rhyolite A and has six pieces of cortex present, which is the second highest amount of group A rhyolite cortex in a site assemblage.

Batza Téna material also does not follow the expectation of high cost assemblages with low amounts of cortex regularly. An assemblage, MMK-0005, with the eighth highest cost from Batza Téna has the highest number of artifacts with cortex out of all three materials (n=80). Further, the site CIR-00029 has the highest cost from Batza Téna of all these sites and contains 11 artifacts with cortex, which is the second highest number of artifacts with cortex made of Batza Téna obsidian.

Finally, Wiki Peak material is the most representative of the cortex absence/presence expectation. There is a very small sample of Wiki Peak obsidian artifacts that have cortex in general so it is difficult to distinguish a pattern at all.

Though there are not distinguishable patterns between the cortex presence and cost for each of these materials, the occasions of assemblages that I described having the highest costs from the source and a relatively large number of artifacts with cortex seem to be outliers. It is likely with a complete data set on the absence and presence of cortex for each material that a pattern may develop that represents the expectations.

Table 4.4 Shows the time to travel to each site from the Rhyolite A source in minutes (cost). The costs are organized in increasing order. The percent of material (by number of artifacts) with cortex absent and present at each site is listed in the other two columns. Recall the lowest cost away from the Rhyolite A source this material traveled was 5,112,057 minutes and the highest was 12,363,277 minutes.

Site	Rhyolite A Cost Relative Minutes	Percent Rhyolite Cortex Absent	Percent Rhyolite Cortex Present	Number Cortex Absent	Number Cortex Present
HEA-00007	4906882	73.2	26.8	41	15
HEA-00005	4934361	81.8	18.2	18	4
HEA-00086	5006932	100	0	5	0
HEA-00008	5076413	91	9	10	1
HEA-00138	5088991	100	0	2	0
HEA-00240	5112058	94.4	5.6	17	1
HEA-00035	5151270	100	0	3	0
HEA-00133	5275834	100	0	2	0
FAI-00142	5578355	100	0	6	0
HEA-00128	5601640	100	0	1	0
FAI-00146	5622694	75	25	6	2
FAI-00241	5626530	100	0	2	0
FAI-00205	5723521	100	0	1	0
FAI-00206	5815703	88.9	11.1	16	2
FAI-01357	5912249	50	50	1	1
FAI-00193	5976802	100	0	1	0
FAI-00171	6004870	0	100	0	1
FAI-00215	6102900	100	0	1	0
FAI-00035	6106625	100	0	7	0
FAI-00194	6110254	100	0	8	0
FAI-00197	6112749	71.4	28.6	5	2
FAI-00195	6264514	100	0	1	0
FAI-00047	6344167	100	0	1	0
FAI-00086	6368662	100	0	3	0
FAI-00087	6371211	88.9	11.1	8	1
FAI-00088	6408649	88.9	11.1	8	1
MMK-00004	6435823	100	0	6	0
HEA-00163	6683398	100	0	2	0
LIV-00041	6689000	100	0	8	0

XBD-00106	6775800	100	0	4	0
FAI-00091	6781474	100	0	9	0
LIV-00051	6867390	100	0	1	0
XBD-00026	6876958	100	0	2	0
XMH-00206	6979644	100	0	3	0
XMH-00315	6997283	100	0	4	0
XMH-00280	7002720	100	0	1	0
XMH-01227	7155131	100	0	1	0
XMH-00914	7220840	0	100	0	1
XMH-00910	7247712	100	0	1	0
XMH-00915	7248443	100	0	2	0
XMH-01115	7653613	100	0	4	0
HEA-00148	9201714	100	0	1	0
HEA-00001	9251846	53.8	46.2	7	6
HEA-00002	9334081	100	0	2	0
FAI-00148	9790633	100	0	2	0
FAI-00149	9886815	0	100	0	2
XMH-00139	12363227	100	0	1	0
XMH-00149	12383977	100	0	1	0

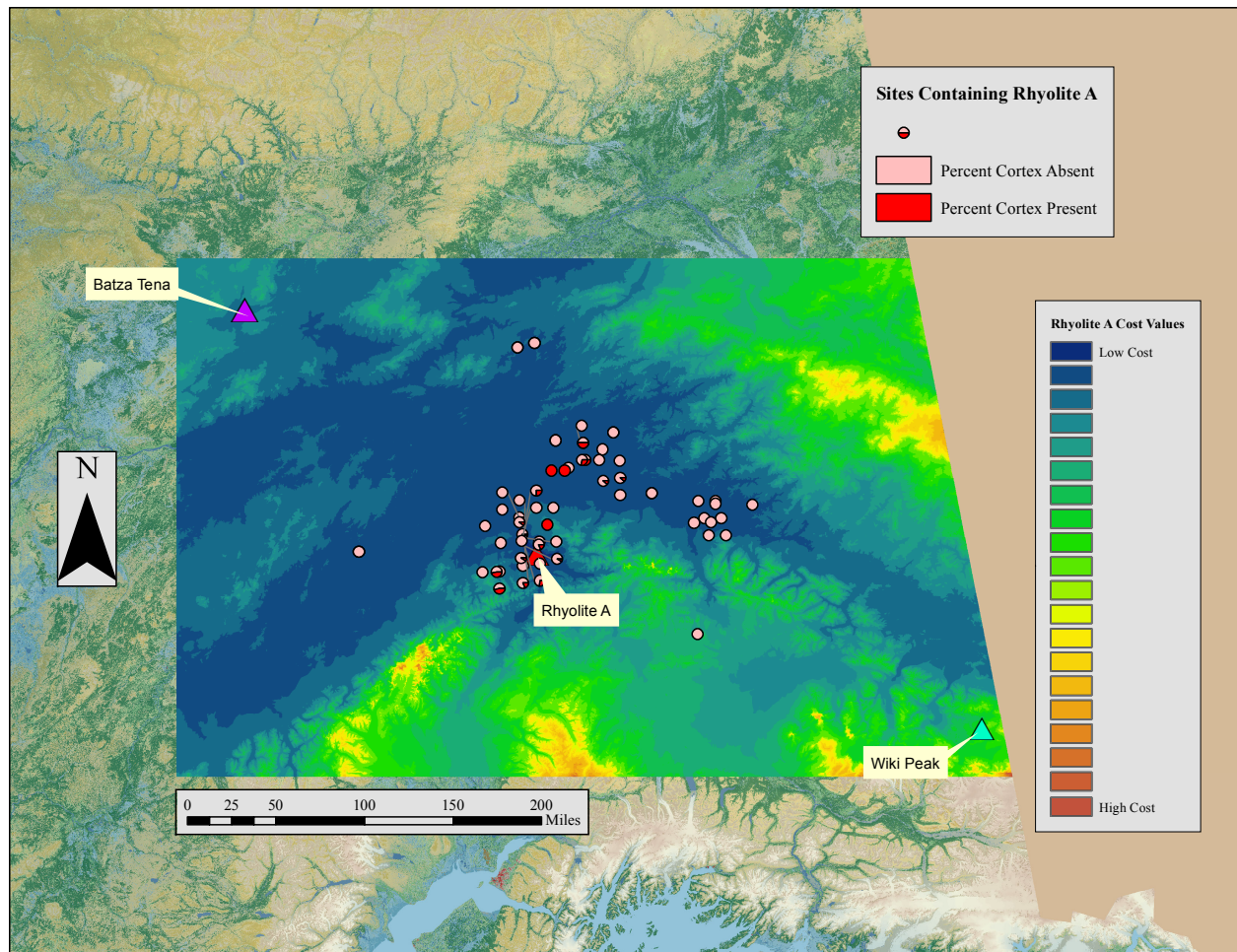


Figure 4.10 is a geographic representation of Table 4.4. The map shows the sites that contain information on the absence and presence of group A rhyolite cortex in their site assemblages in relation to the Rhyolite A source. The sites are shown on the anisotropic cost surface which gives value to the time it takes to travel from the Rhyolite A source and the values are represented by a color scale.

Table 4.5 Shows the time to travel to each site from the Batza Téna source in minutes (cost). The costs are organized in increasing order. The percent of material (by number of artifacts) with cortex absent and present at each site is listed in the other two columns. Recall the lowest cost away from Batza Téna this material traveled was 3,783,770 minutes and the highest was 6,780,815 minutes.

Site	Batza Téna Cost Relative Minutes	Percent Batza Téna Cortex Absent	Percent Batza Téna Cortex Present	Number Cortex Absent	Number Cortex Present
FAI-01661	3770646	100	0	4	0
LIV-00127	3783770	84.6	15.4	11	2
FAI-01356	3961903	100	0	3	0
FAI-00001	3965391	85.7	14.3	6	1
FAI-00035	4135860	57.1	42.9	4	3
FAI-00194	4162977	100	0	1	0
MMK-00012	4167114	30.8	69.2	4	9
MMK-00005	4182770	49	51	77	80
XBD-00301	4349724	100	0	1	0
LIV-00041	4486287	50	50	2	2
FAI-00045	4495776	0	100	0	1
LIV-00051	4664677	100	0	2	0
XBD-00131	4724692	87.5	12.5	14	2
XBD-00159	4725299	50	50	1	1
XBD-00156	4741972	85	15	17	3
XBD-00106	4837171	25	75	1	3
XBD-00020	5041015	100	0	4	0
XMH-00904	5243498	75	25	3	1
XMH-00878	5249662	100	0	2	0
XMH-00874	5299867	100	0	26	0
FAI-00206	5308216	100	0	1	0
XBD-00107	5342728	0	100	0	1
HEA-00005	5344091	100	0	7	0
XMH-00942	5399328	100	0	1	0
XMH-00977	5703117	100	0	1	0
XMH-01116	5769032	100	0	1	0
XMH-00277	5816995	100	0	2	0
XBD-00094	6069855	80	20	4	1
MMK-00027	6336084	0	100	0	1
TNX-00004	6515306	100	0	2	0
HEA-00062	6750604	33.3	66.7	2	4
CIR-00029	6780815	73.8	26.2	31	11

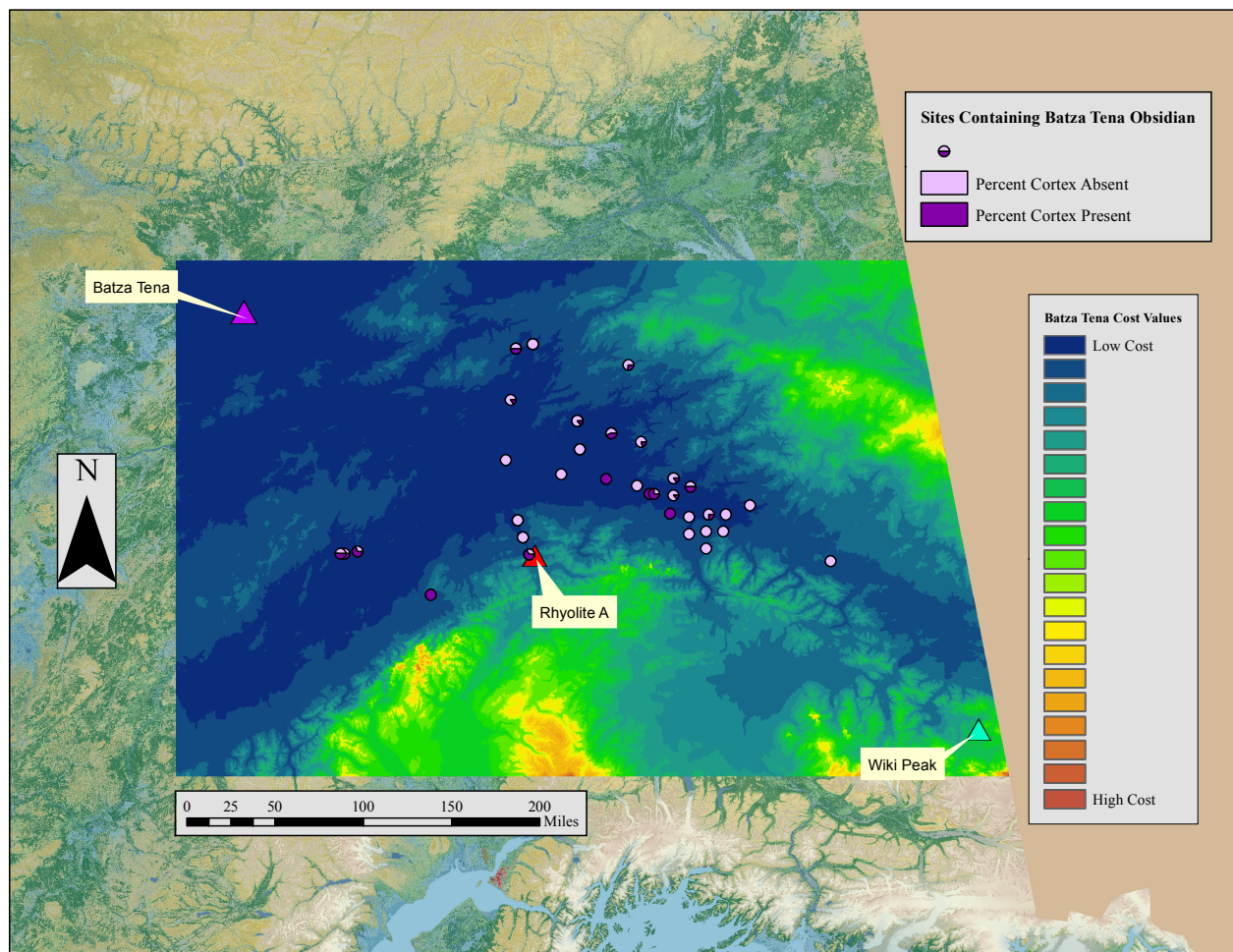


Figure 4.11 is a geographic representation of Table 4.5. The map shows the sites that contain information on the absence and presence of Batza Tena cortex in their site assemblages in relation to the Batza Tena source. The sites are shown on the anisotropic cost surface, which gives value to the time it takes to travel from the Batza Tena source and the values are represented by a color scale.

Table 4.6 Shows the time to travel to each site from the Wiki Peak source in minutes (cost). The costs are organized in increasing order. The percent of material (by number of artifacts) with cortex absent and present at each site is listed in the other two columns. Recall the lowest cost away from Wiki Peak the material traveled was 9,144,066 minutes and the highest was 14,884,907 minutes.

Site	Wiki Peak Cost Relative Minutes	Percent Wiki Peak Cortex Absent	Percent Wiki Peak Cortex Present	Number Cortex Absent	Number Cortex Present
NAB-00020	9085098	50	50	1	1
TNX-00004	9144066	75	25	6	2
XBD-00020	10531319	100	0	2	0
XBD-00026	10602948	100	0	2	0
XMH-00874	10855767	100	0	1	0
XMH-00920	10928931	100	0	1	0
XBD-00159	10966595	100	0	1	0
XMH-00292	10974443	100	0	2	0
XBD-00071	10987926	100	0	13	0
XBD-00131	11057114	90.5	9.5	19	2
XMH-00881	11164240	100	0	1	0
XMH-00949	11605150	100	0	1	0
FAI-01357	11682120	100	0	1	0
FAI-00044	11770959	100	0	1	0
FAI-00035	11772699	100	0	1	0
FAI-00197	11882617	100	0	2	0
LIV-00051	12769506	100	0	1	0
FAI-00206	13154272	100	0	2	0
HEA-00005	13190140	91	9	10	1

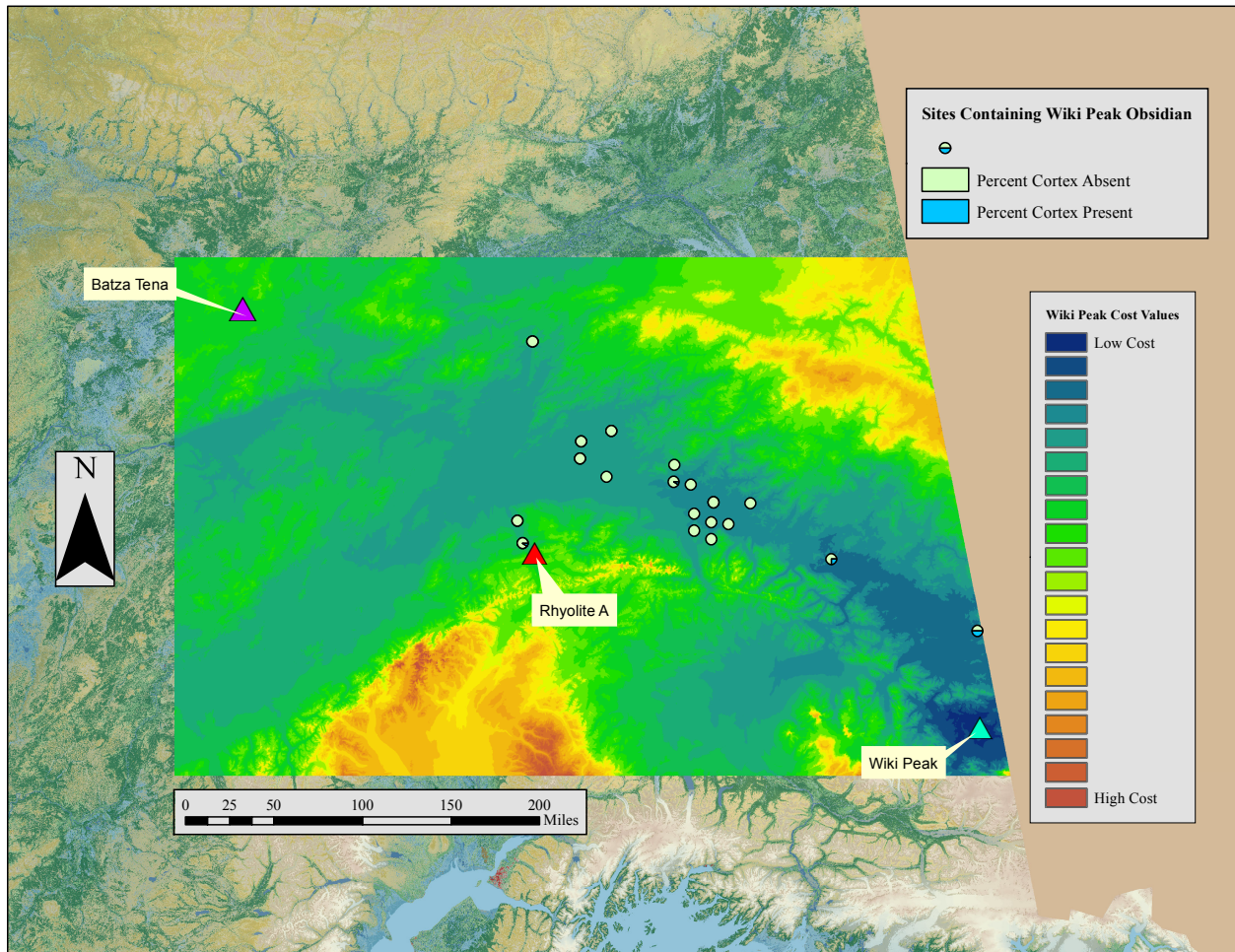


Figure 4.12 is a geographic representation of Table 4.6. The map shows the sites that contain information on the absence and presence of Wiki Peak cortex in their site assemblages in relation to the Wiki Peak source. The sites are shown on the anisotropic cost surface, which gives value to the time it takes to travel from the Wiki Peak source and the values are represented by a color scale.

Sites on the Cost Landscape

All the following maps (Figures 4.13, 4.14, and 4.15) are visual representations of the scatterplots shown in the section *Relationship between Material Weight and Material Cost* (Figures 4.7, 4.8, 4.9). The sites are represented by pie charts of the percent of raw materials at the site. The percent was calculated by the amount of material by weight. The background shows the areas of high and low cost radiating from each source. The low costs on the landscape are represented by dark blue and high costs are represented by orange. It is apparent that most of the sites occur in the Tanana Valley along the river, which is the lowest cost area from all the sources. All the sites in all three images are in the same location; only the cost surfaces are different because they represent the cost of traveling from each source. The color scale that represents the cost values from the sources are uniform between the maps, therefore the maps can be accurately compared by color. Wiki Peak is the most costly material to obtain in the Tanana River Drainage (Figure 4.14). Ironically, Rhyolite A is located in the center of the Tanana River Drainage (Figure 4.15), a relatively close distance from all the sites, however, is more costly to obtain than Batza Téna obsidian which is located approximately 300 miles away from most of the sites in the Tanana River Drainage (Figure 4.13). Recalling that Tobler's Hiking Function takes into account distance and slope, Rhyolite A may be more costly than Batza Téna due to its location in steep terrain.

When looking at the percent of the three raw materials at the sites in these maps, Wiki Peak material is far less abundant than Batza Téna and Rhyolite A material in the sites that were considered relevant to this study. Group A rhyolite material is the most abundant among the selected sites, occurring in 21 site assemblages. Batza Téna material is the next most prevalent

material occurring at 19 of the selected sites. Between these two prevalent materials there is no relationship between the cost of acquisition and amount of material, however it is interesting that sites that contain both Batza Téna and rhyolite materials are very few (n=7 out of 35). The maps show that most of the 35 relevant sites chosen for this study are either dominated by obsidian or rhyolite. The highest cost distance that Rhyolite A traveled was 12,363,227 minutes. The rhyolite tool that traveled this distance was a single projectile point that weighed 35.03 grams. The highest cost that Batza Téna obsidian traveled was 6,780,815 minutes, this material made up 94.94% of the site (CIR-029) and consisted of 9.6 grams of debitage, 31.91 grams of formalized tools, and 2.4 grams of microblade technology. The highest cost that Wiki Peak traveled was 14,884,907 minutes but this material only made up 0.22% of the site (CIR-029) and consisted of 0.1 grams of microblade technology.

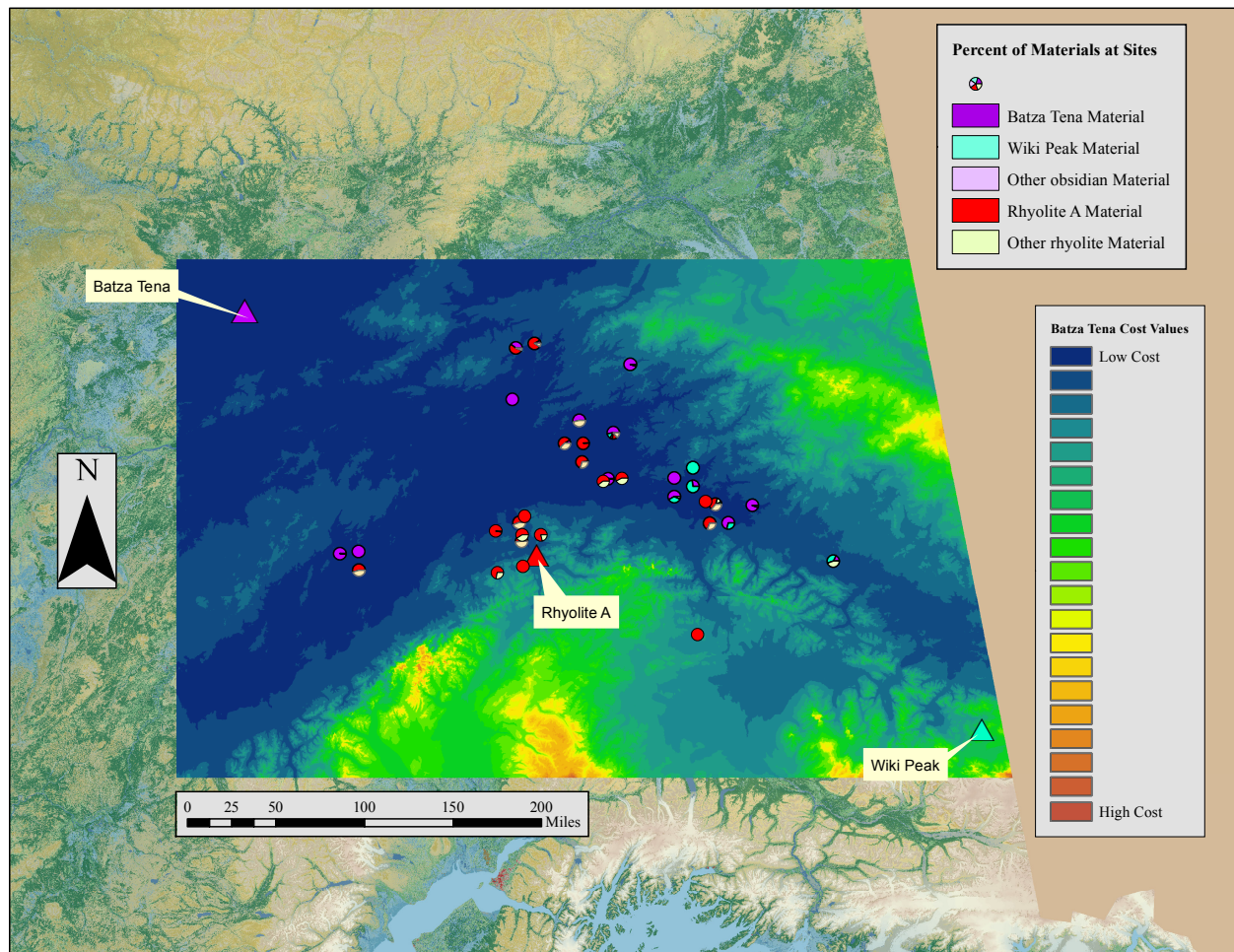


Figure 4.13 Shows the anisotropic cost surface created for traveling from the Batza Téna source. The sites on the landscape are the 35 sites that were selected to analyze the relationship between raw material weight and cost. The sites are marked by a pie chart representing the percent of raw materials located at each site. It is the same cost surface visible in Figure 4.11.

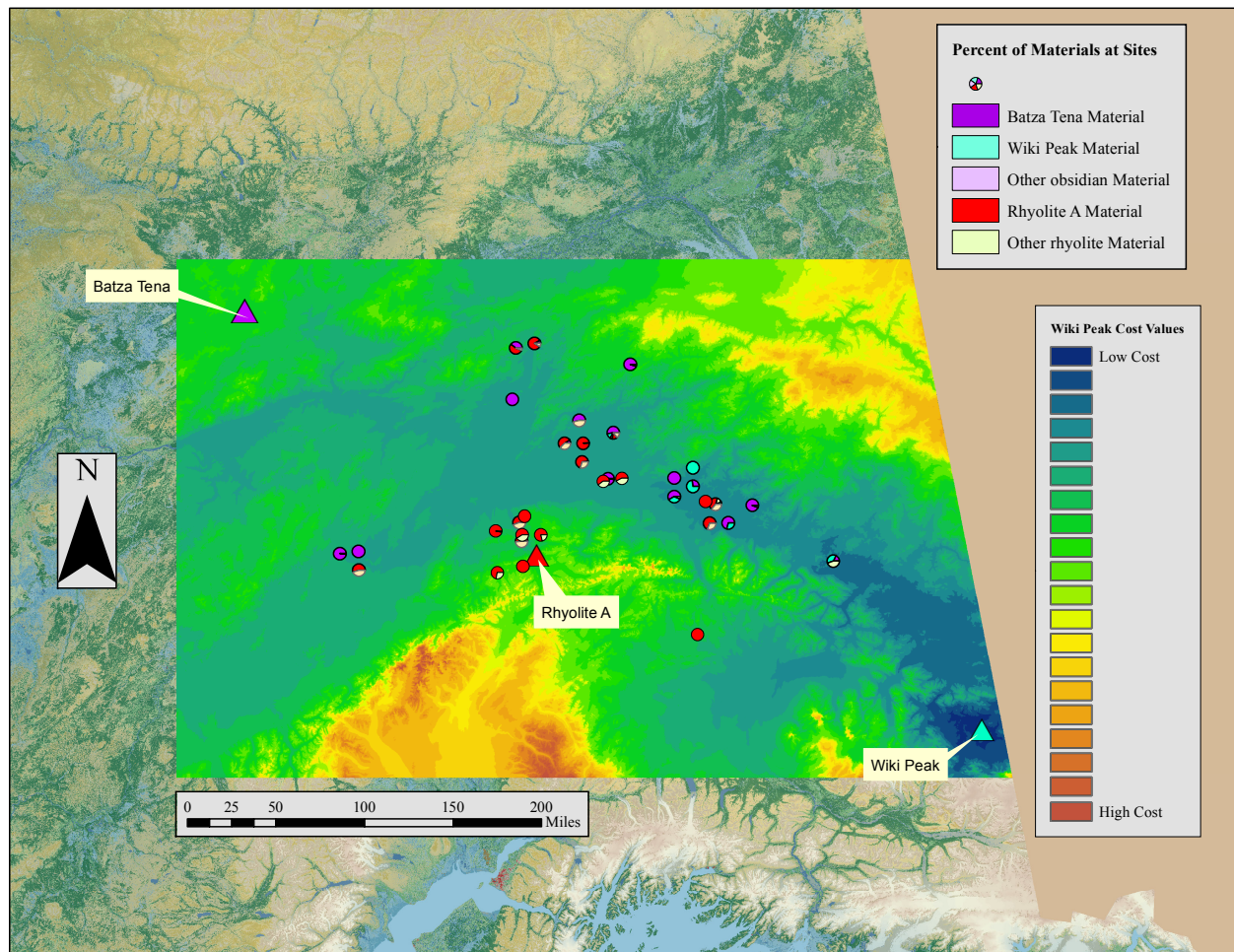


Figure 4.14 Shows the anisotropic cost surface created for traveling from the Wiki Peak source. The sites on the landscape are the 35 sites that were selected to analyze the relationship between raw material weight and cost. The sites are marked by a pie chart representing the percent of raw materials located at each site. It is the same cost surface visible in Figure 4.12.

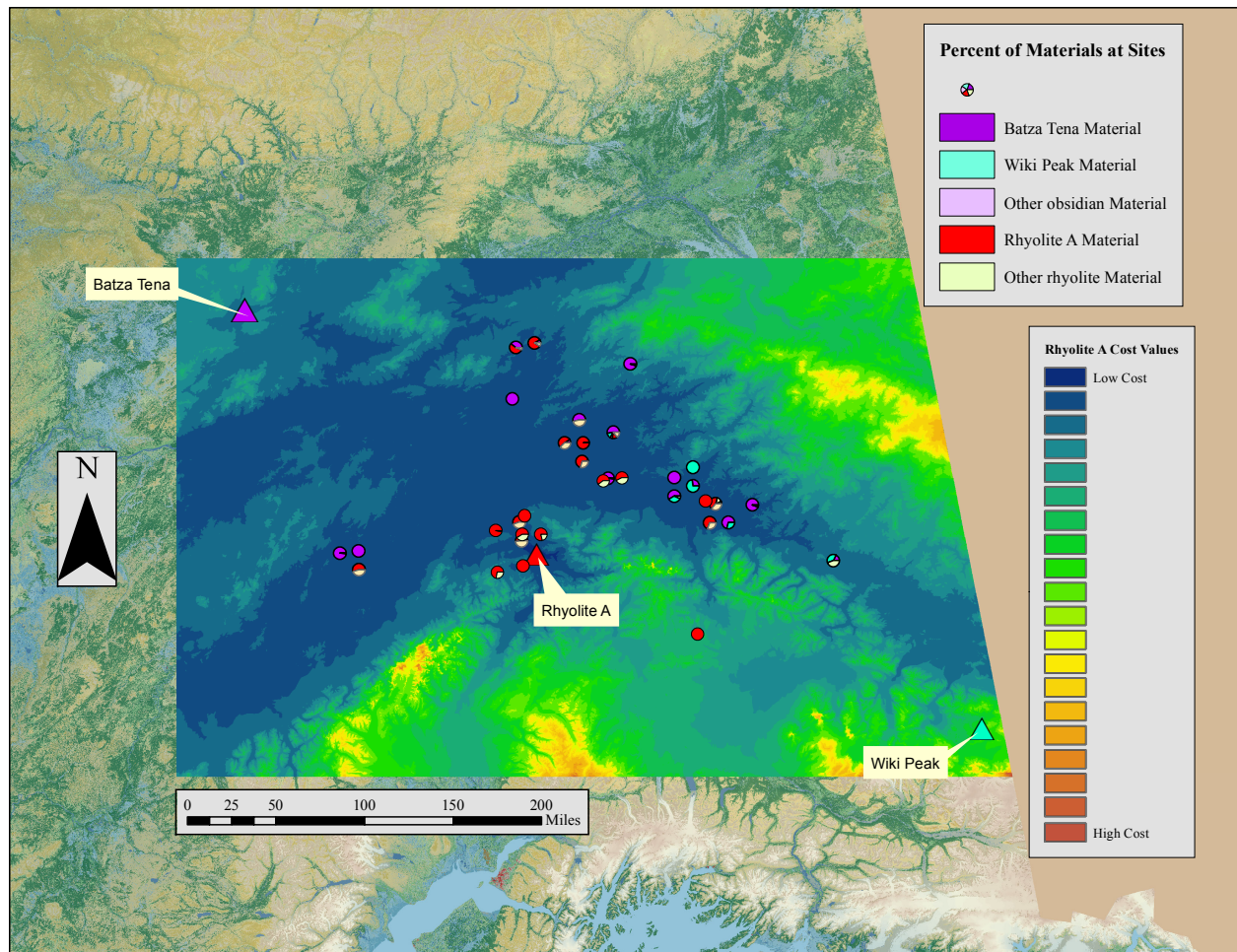


Figure 4.15 Shows the anisotropic cost surface created for traveling from the estimated Rhyolite A source. The sites on the landscape are the 35 sites that were selected to analyze the relationship between raw material weight and cost. The sites are marked by a pie chart representing the percent of raw materials located at each site. It is the same cost surface visible in Figure 4.10.

Tool Classification Breakdown of Selected Sites

In the previous section, *Sites on the Cost Landscape*, it was stated that sites of particular interest were those that contained both Batza Téna obsidian and rhyolite because there were very few. The sites that are representative of this picture are LIV-041, FAI-001, FAI-035, and LIV-051. These sites assemblages that stand out may be useful to offer explanations for the lack of patterning between raw material amount and cost. Pie charts (Figures 4.16, 4.18, 4.20, and 4.22)

show the percent raw material types at each of these sites. Pie charts (Figures 4.17, 4.19, 4.21, and 4.23) show the percent of each tool type of each raw material at the sites. At this time it will be necessary to refer back to Figures 4.3 through 4.6, which offer an overview of the tool type break down for all obsidian and all rhyolite in the Tanana River Drainage in order to compare these five sites' pie charts to the overall sample of artifacts in the study area.

Figures 4.3 and 4.4 show the percent by weight and count of each tool type made of obsidian in the Tanana River Drainage. Figures 4.5 and 4.6 show the percent by weight and count of each tool type for the rhyolite materials. For both obsidian and rhyolite there is a large number of pieces of debitage but each individual piece is small and have less mass than a formalized tool for example. Therefore, using weight as a variable to evaluate the amount of a material moderates the values of a large number of small tools and a small number of large tools. The pie charts based on weight should be used to compare to the individual site percent pie charts because these are also based off of weight. However, when comparing the obsidian to rhyolite in both cases (count and weight) there is a greater amount of formalized and microblade rhyolite tools, which are the two tools that require the most fine and skilled knapping techniques.

It has been well documented through experimental flint knapping that obsidian is the preferred material for making these detailed tools because the characteristics of the material allows for it to fracture conchoidally and produce very sharp edges. Rhyolite appears to be costly to transport but is still used for hunting tools, such as projectile points and other heavy bifacial technology even though it has slightly courser flaking properties than obsidian. It is possible this material was collected opportunistically when the people went to hunt and the tools did not have long use lives, while the obsidian tools may have been reused and retouched more.

Sites of interest in the Tanana River Drainage

In order to address the failure of the results to meet the preliminary hypothesis I seek to find any patterns that deviate from the overall sample, which may elicit raw material preference for certain tool types or suggest the site function where these material were used. There are five sites that stand out from the 35 relevant sites on the cost surface maps because they contain both Batza Téna and rhyolite material. Most of the 35 sites are either entirely made up of obsidian and rhyolite. The site LIV-041 is made up of 39.75% Batza Téna obsidian, 54.07% Rhyolite A, and 6.17% rhyolite from other unknown sources (Figure 4.16). The Batza Téna obsidian tools consist of one expedient tool and three formalized tools (two bifacial projectile points and one uniface). The Rhyolite A tools consist of two microblade cores and the other rhyolite tool was a microblade core as well (Figure 4.17). Site FAI-001 is made up of 54.05% Batza Téna obsidian and 45.95% rhyolite from other unknown sources (Figure 4.18). The Batza Téna artifacts are debitage and two formalized tools (unifaces). The other rhyolite artifacts consist of one expedient tool and three formalized tools (two unifaces and one blade) (Figure 4.19). Site FAI-035 is interesting because it is made up of all the different materials. It is 53.70% Batza Téna obsidian, 14.49% Wiki Peak obsidian, 5.87% obsidian from other unknown or small sources, 13.27% Rhyolite A, 13.67% other unknown rhyolite (Figure 4.20). Batza Téna obsidian artifacts consist of debitage, a formalized tool, microblade technology, and undetermined lithics. The Wiki Peak artifacts are an expedient tool, two formalized tools, and undetermined lithics. The other obsidian artifacts at this site are undetermined lithics. The Rhyolite A artifacts are debitage, two formalized tools, and microblade technology. The other rhyolite artifacts are debitage, an expedient tool, and a formalized tool (Figure 4.21). Site LIV-051 contains a smaller amount of

obsidian material but the tool types are still representative of the overall tool type breakdown for obsidian and rhyolite of all the sites (Figure 4.22 and 4.23)

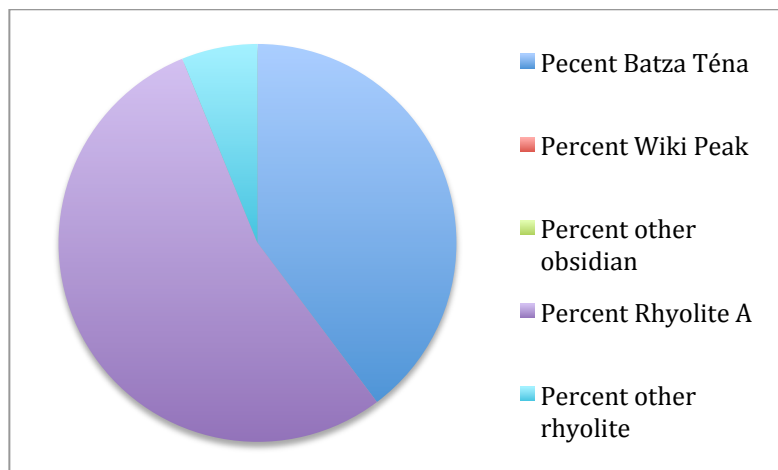


Figure 4.16 Shows the percent of different materials at the site LIV-0041.

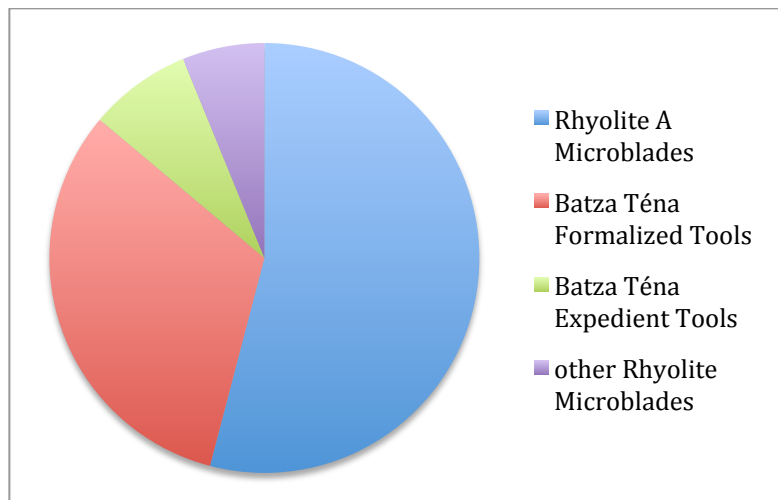


Figure 4.17 Shows the percent of tool types of the different materials at the site LIV-0041.

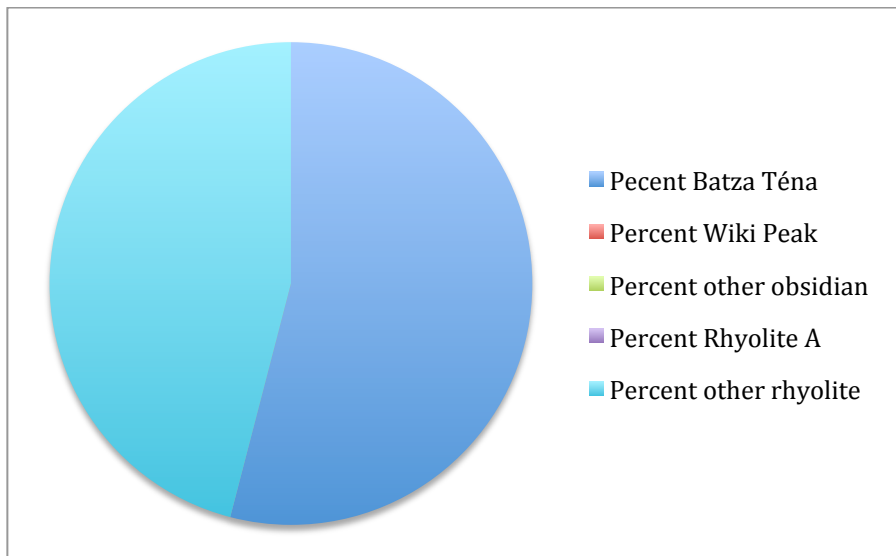


Figure 4.18 Shows the percent of different materials at the site FAI-0001.

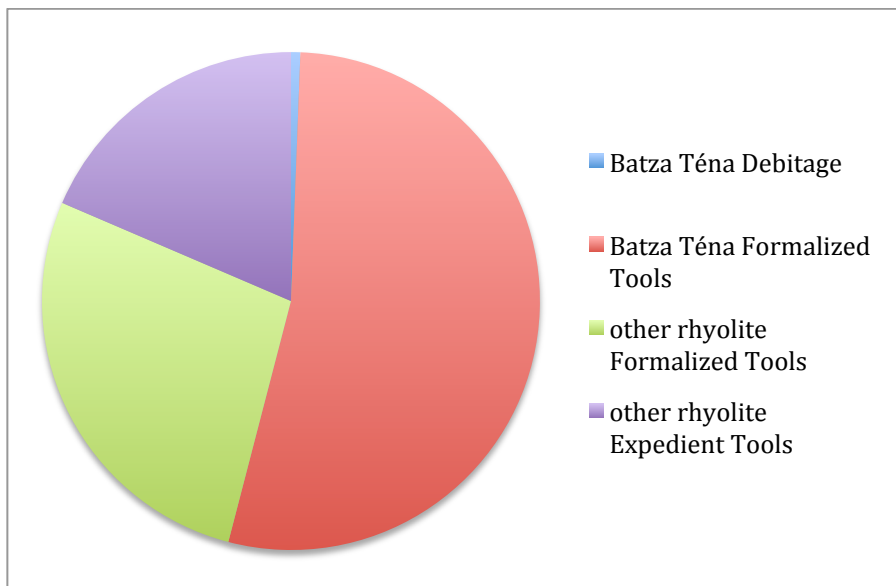


Figure 4.19 Shows the percent of tool types of the different materials at the site FAI-0001.

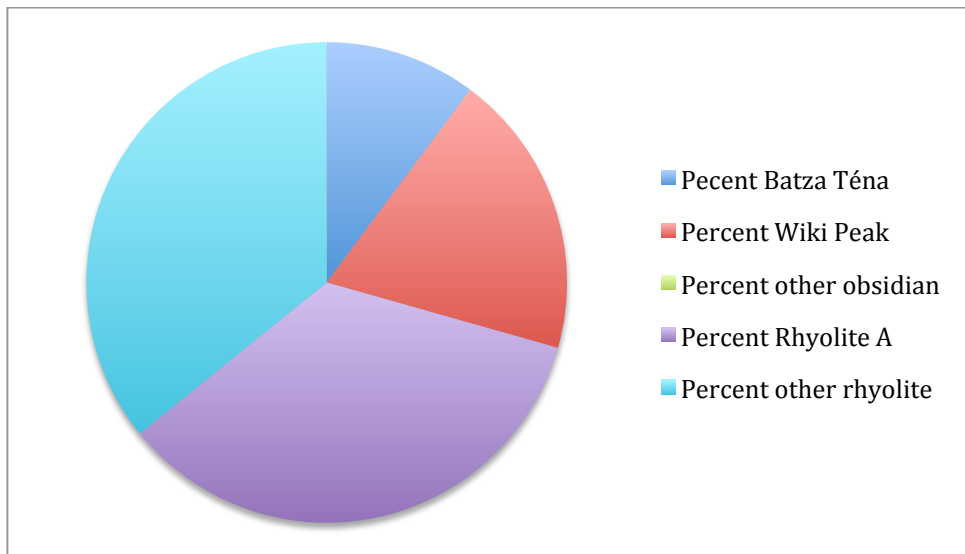


Figure 4.20 Shows the percent of different materials at the site FAI-0035.

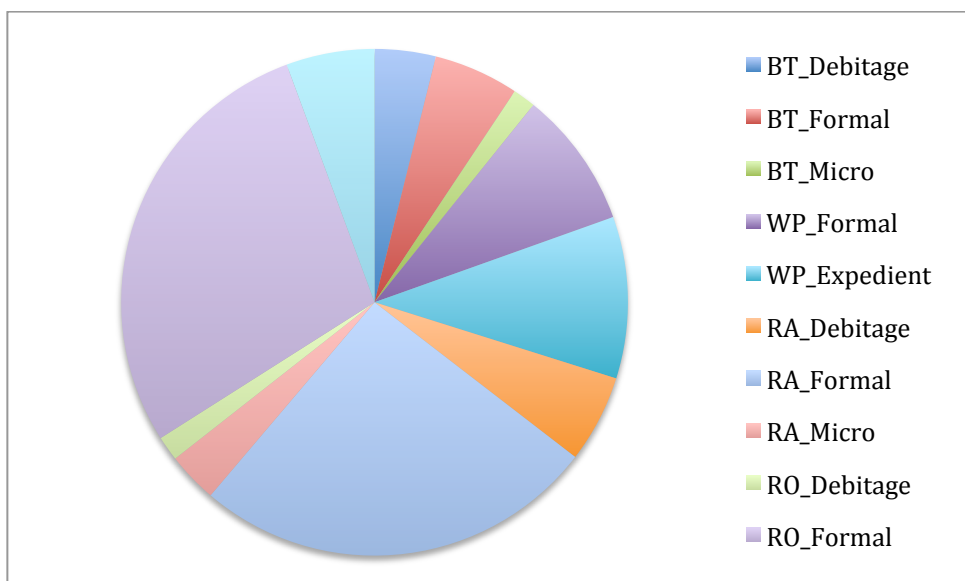


Figure 4.21 Shows the percent of tool types of the different materials at the site FAI-0035. The abbreviations mean the following: BT, percent Batza Téna; WP, percent Wiki Peak; RA, percent Rhyolite A; RO, percent other rhyolite; Micro, microblade technology; Formal, formalized artifacts; Expedient, expedient artifacts

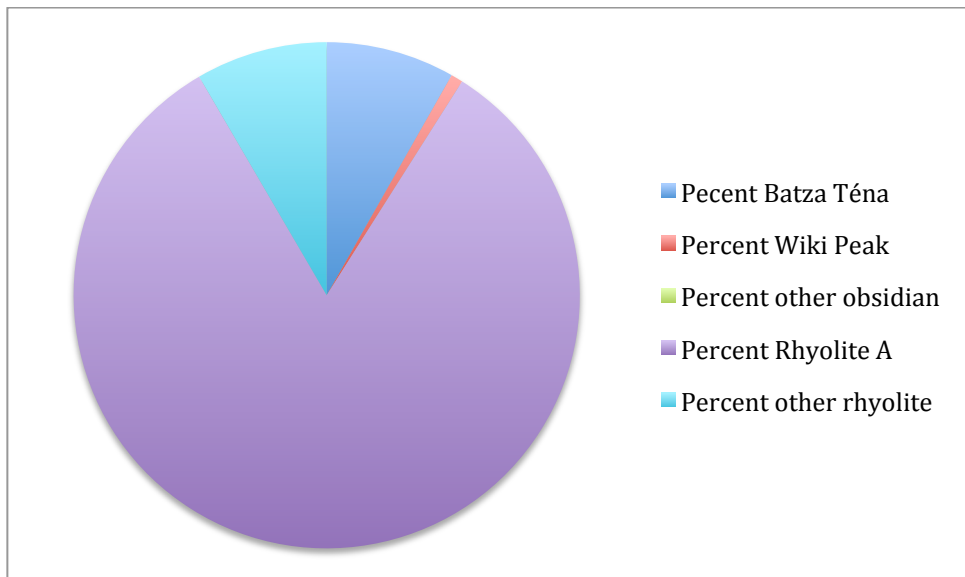


Figure 4.22 Shows the percent of different materials at the site LIV-0051.

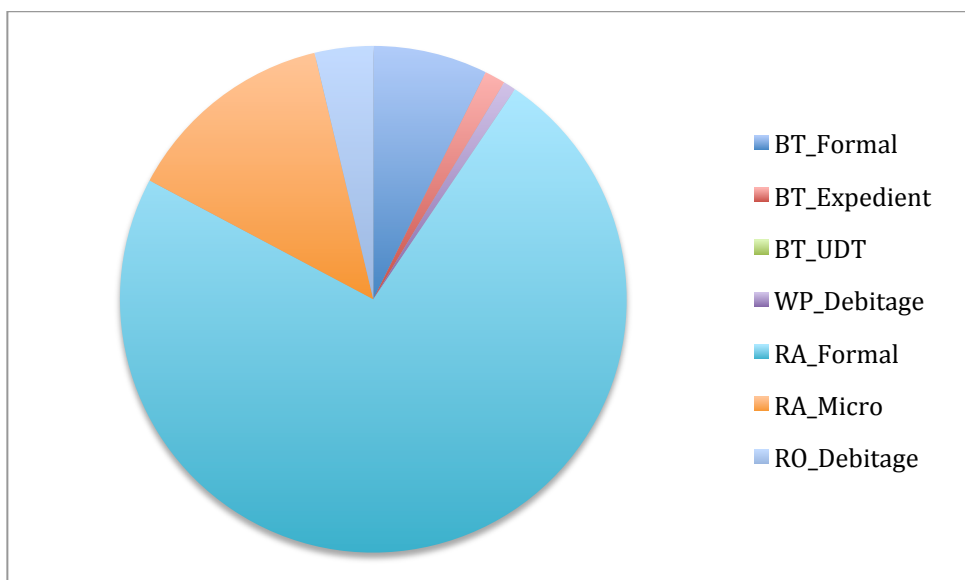


Figure 4.23 Shows the percent of tool types of the different materials at the site LIV-0051.

Rhyolite and Obsidian Sites by Physical Location (Mountain Ridges vs Tanana River Valley)

Since the sites that contained both obsidian and rhyolite were not significantly different from the overall tool classification breakdown of all the obsidian and rhyolite lithics in the entire dataset, I looked at how the sites made up primarily of one material were distributed on the landscape. As visible in Figures 4.13, 4.14, and 4.15, site assemblages that are located in the mountains closest to the Rhyolite A source are mainly made of rhyolite. Most site assemblages in the Tanana Valley fall along the Tanana River and are either made of rhyolite or obsidian.

The following results show that there is a difference in the rhyolite tool assemblages in the mountains close to the Rhyolite A source and the rhyolite tool assemblages in the Tanana Valley. The rhyolite assemblages in the mountains are dominated by bifacial technology, while unifacial tools are almost completely absent from these sites. There is one utilized flake, which was considered a unifacial tool by the original analysts of the dataset present at one of the sites located in the mountains near the Rhyolite A source. On the other hand, the rhyolite assemblages in the Tanana Valley are dominated by unifacial technology and microblade cores. Table 4.7 shows the sites that are dominated by Rhyolite A and other rhyolite that are in the mountains around Rhyolite A source. Table 4.8 shows the sites that are dominated by rhyolite that are located along the Tanana River in the Tanana Valley. The site assemblages along the Tanana River that are dominated by obsidian mainly contain unifacial tools and microblades as shown in Table 4.9. The tool types in the few site assemblages that contain both obsidian and rhyolite are shown in Tables 4.10 and 4.11.

Table 4.7 Rhyolite Mountain Sites: Sites that contain all (or almost all) rhyolite material in the mountains in the vicinity of the estimated Rhyolite A source.

SITE	Debitage	Unifacial Tool	Bifacial Tool	Microblade Technology	Flake Tool	Core
HEA-0163	0	0	2	0	0	0
FAI-00146	3	0	4	0	0	1
FAI-00091	9	0	1	0	0	0
FAI-00241	2	0	0	0	0	0
FAI-00206	15	0	10	2 (1 core)	0	1
HEA-0035	6	0	0	2	0	0
HEA-0002	0	1	2	0	0	0
FAI-00142	7	0	0	1	0	0

Table 4.8 Rhyolite Tanana River Valley Sites: Sites that contain all (or almost all) rhyolite material in the valley among other sites that contain obsidian.

SITE	Debitage	Unifacial Tool	Bifacial Tool	Microblade Technology	Flake Tool
FAI-1357	0	1	1	0	0
FAI-0197	1	3	2	5 (cores)	0
FAI-0194	8	2	0	1 (core)	0
FAI-0088	10	1	0	1 (core)	0
FAI-0087	8	0	0	2	0
XBD-0078	0	0	0	1 (core)	0
XMH-0910	0	1	2	0	0
XBD-0026	3	3	0	0	0

Table 4.9 Obsidian Tanana River Valley Sites: Sites in the Tanana River Valley that contain all (or a majority) of obsidian material. Bifacial Pressure Flake is represented by the initials bpf.

SITE	Debitage	Unifacial Tool	Bifacial Tool	Microblade Technology	Flake Tools
LIV-00127	12	1	0	0	0
FAI-00045	2	1	0	0	1
XBD-0156	19 (5bpf)	3	2	21	1
CIR-00029	40 (7bpf)	4	0	8	0
XBD-0071	32 (5bpf)	0	0	2	0
XBD-0159	1	0	0	0	2

Table 4.10 Tanana River Valley Sites: Sites containing a relatively equal amount of obsidian and rhyolite. This table represents the tool types made of obsidian.

SITE	Obsidian Debitage	Obsidian Unifacial Tool	Obsidian Bifacial Tool	Obsidian Microblade Technology	Obsidian Flake Tool	Obsidian Cores
LIV-0041	0	1	2	0	1	0
FAI-0001	10	2	0	0	0	0
FAI-0035	6	0	3	12	1	1
LIV-0051	1	0	1	0	1	0

Table 4.11 Tanana River Valley Sites: Sites containing a relatively equal amount of obsidian and rhyolite. This table represents the tool types made of rhyolite.

SITE	Rhyolite Debitage	Rhyolite Unifacial Tools	Rhyolite Bifacial Tools	Rhyolite Microblade Technology	Rhyolite Flake Tools	Rhyolite Cores
LIV-0041	0	0	0	9 (cores)	0	0
FAI-0001	0	3	1	0	0	0
FAI-0035	4	3	1	2 (1 core)	0	0
LIV-0051	1	1	0	2 (cores)	0	0

Weights of Obsidian Tools Compared to Rhyolite Tools

The percentage of each tool type of a material is a comparison of the amounts different tool types in one material. While this is interesting because it shows which tool type was made the most for each material, Figure 4.10 shows comparison of the weights of each tool type between obsidian and rhyolite materials. This comparison can be helpful to hypothesize about differential preference and use of the two materials. There are more obsidian artifacts than rhyolite artifacts in every lithic classification category except the formalized artifact category. There are 35 more rhyolite formalized artifacts than obsidian but the total weight of these rhyolite formalized artifacts is much heavier than the obsidian tools. It is interesting that

generally there are more formalized artifacts made of rhyolite than obsidian, as reflected in Table 4.10, because the flaking properties of obsidian is often preferred for highly technical manufacturing techniques required for making formalized tools. Overall in the assemblages of the Tanana River Drainage there are more rhyolite than obsidian bifacial and unifacial artifacts. There are 30 rhyolite unifaces while there are only 13 obsidian unifaces. There are 35 rhyolite bifaces and only 29 obsidian bifaces. Since rhyolite is actually considered a light (weight) material, there is no significant difference between the mass of obsidian material and rhyolite material. Figure 4.10 shows how much heavier rhyolite artifacts are than obsidian tools in every category by comparing the total weights of the artifact categories for each material to the total number of artifacts in each category.

Table 4.12 Shows a weight comparison of tool types and material.

Primary Lithic Classification	Obsidian Weight Totals	Obsidian Count Totals	Obsidian Average	Rhyolite Weight Totals	Rhyolite Count Totals	Rhyolite Average
Debitage	322.9	517	419.95	2113.245	303	1208.1225
Expedient Artifacts	273.74	98	185.87	564.64	30	297.32
Formalized Artifacts	347.03	87	217.015	2386.12	122	1254.06
Microblade Technology	18.36	62	40.18	496.86	63	279.93

Formalized Tool Weight and Maximum Dimension Comparison

Figures 4.24 through 4.31 reflect that rhyolite unifacial and bifacial tools are considerably heavier and larger their obsidian counterparts. Both the maximum dimension and weight values mirror each other for both materials and both these variables are greater for the rhyolite artifacts than the obsidian artifacts. Therefore, the difference in weights cannot be attributed to rhyolite

being a denser material that is inherently heavier than obsidian. The boxplots, Figures 4.24 through 4.31 show the median, quartiles, and outlier values of the weights or maximum dimensions the artifacts of each material. The results of the boxplots could suggest that obsidian unifacial and bifacial artifacts were smaller than these group A rhyolite artifacts because they were resharpened more than rhyolite a tools. However the results could also simply suggest that smaller tools were manufactured from obsidian in order to conserve the tools were Batza Téna obsidian in order to conserve the obsidian or because the original Batza Téna raw material cobbles were smaller than that of Rhyolite A.

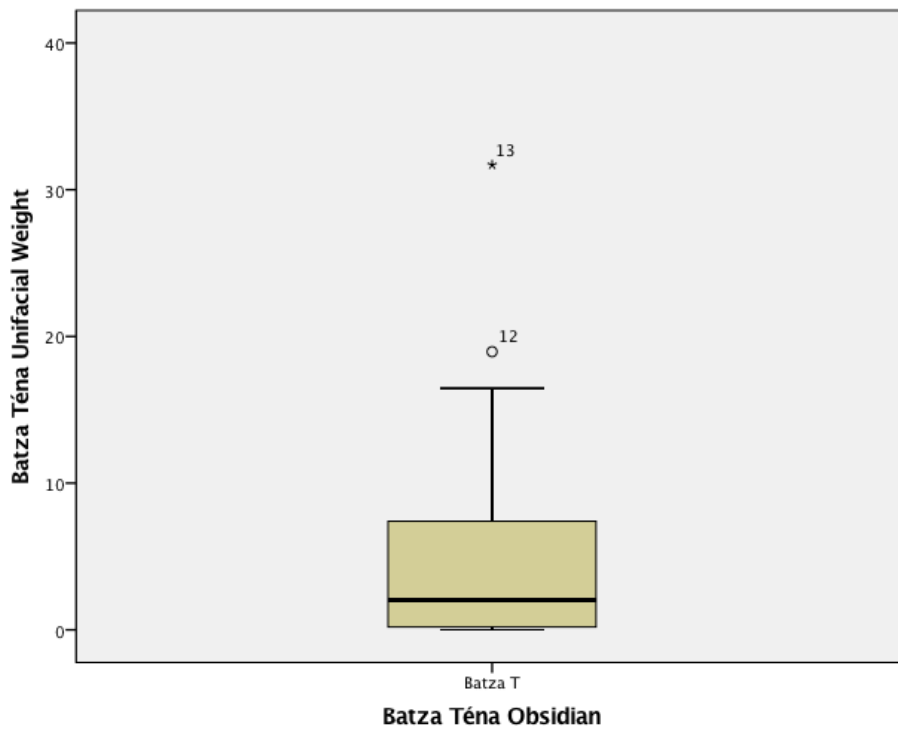


Figure 4.24 Boxplot showing the median, quartiles, and extreme values of the weights of unifacial artifacts made of Batza Téna obsidian.

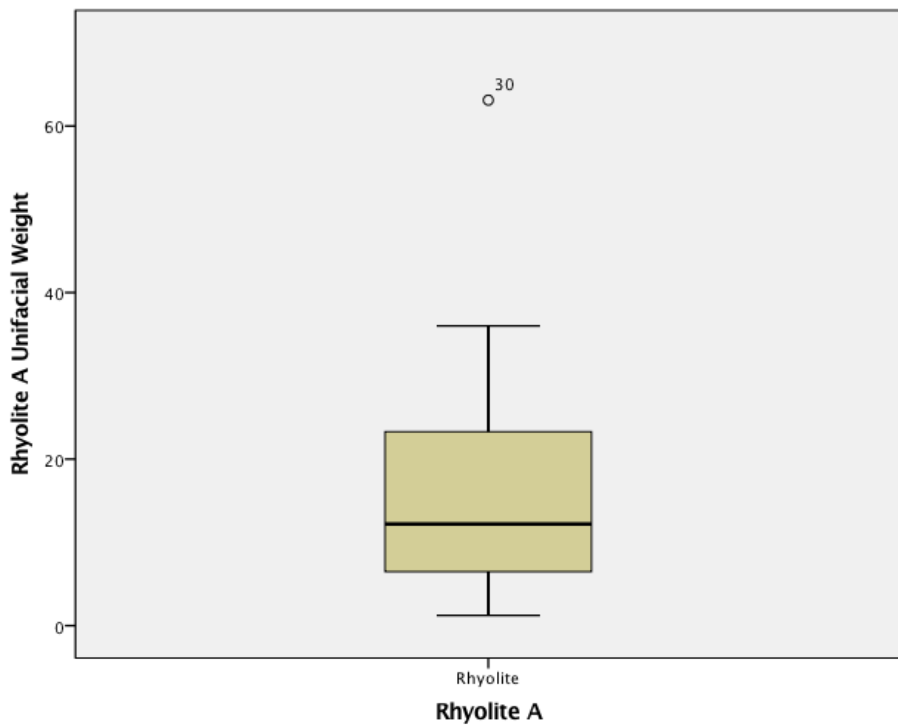


Figure 4.25 Boxplot showing the median, quartiles, and extreme values of the weights of unifacial artifacts made of group A rhyolite.

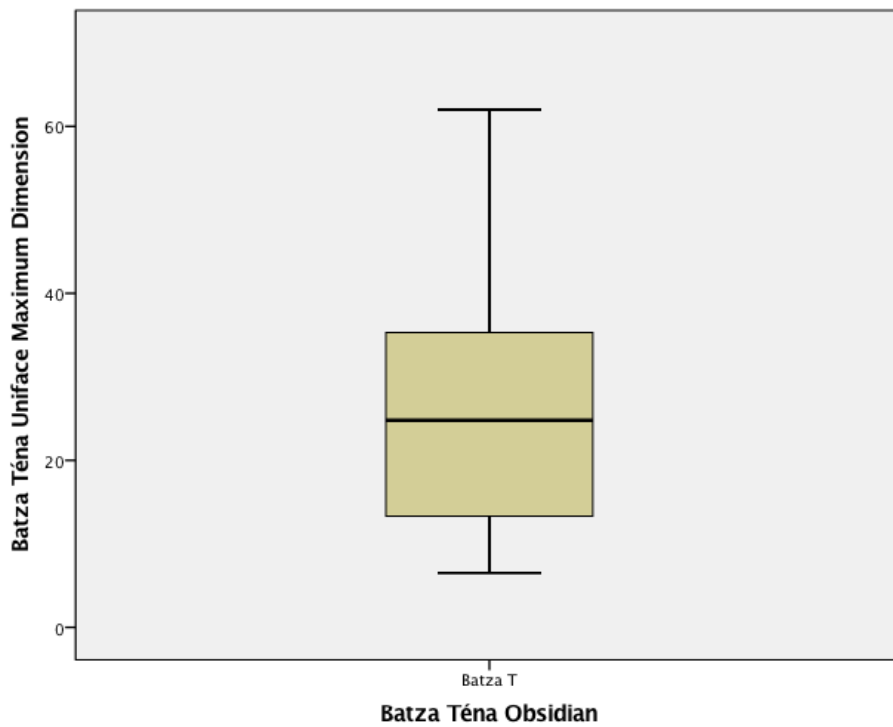


Figure 4.26 Boxplot showing the median, quartiles, and extreme values of the maximum dimension of unifacial artifacts made of Batza Téna obsidian.

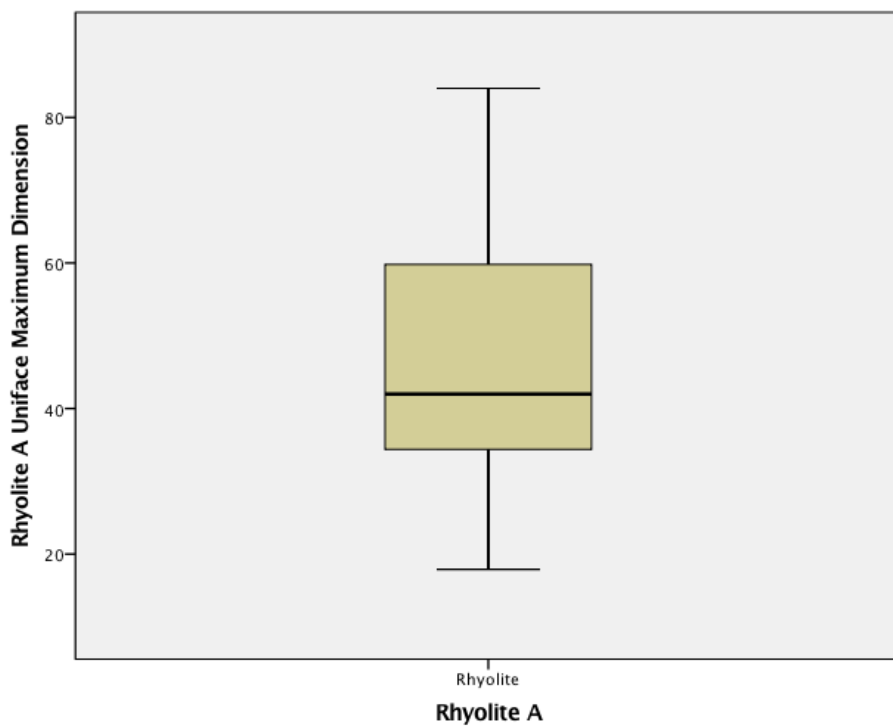


Figure 4.27 Boxplot showing the median, quartiles, and extreme values of the maximum dimension of unifacial artifacts made of group A rhyolite.

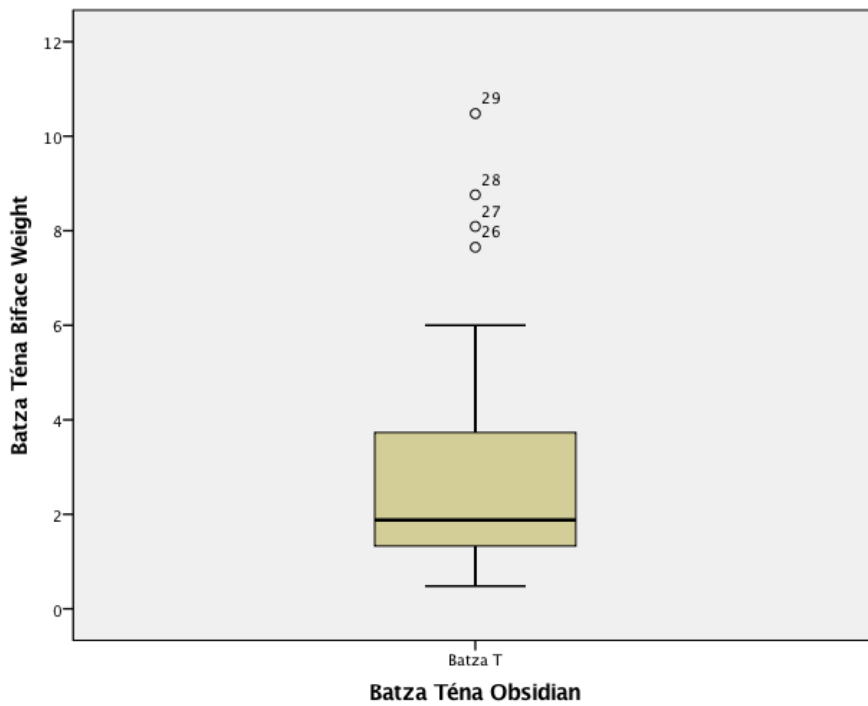


Figure 4.28 Boxplot showing the median, quartiles, and extreme values of the weights of bifacial artifacts made of Batza Téna obsidian.

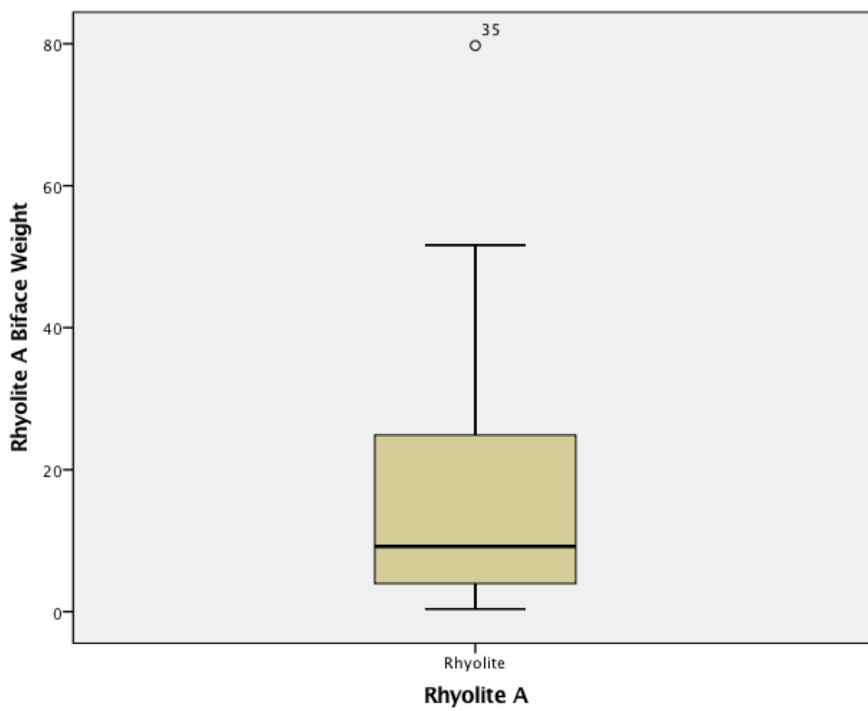


Figure 4.29 Boxplot showing the median, quartiles, and extreme values of the weights of unifacial artifacts made of group A rhyolite.

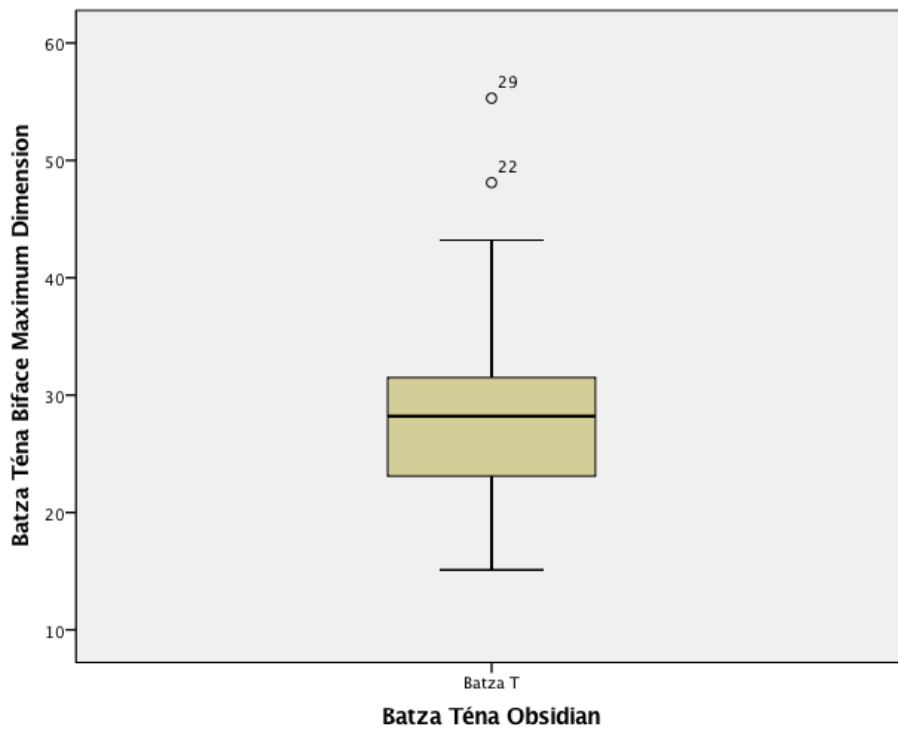


Figure 4.30 Boxplot showing the median, quartiles, and extreme values of the maximum dimension of bifacial artifacts made of Batza Téna obsidian.

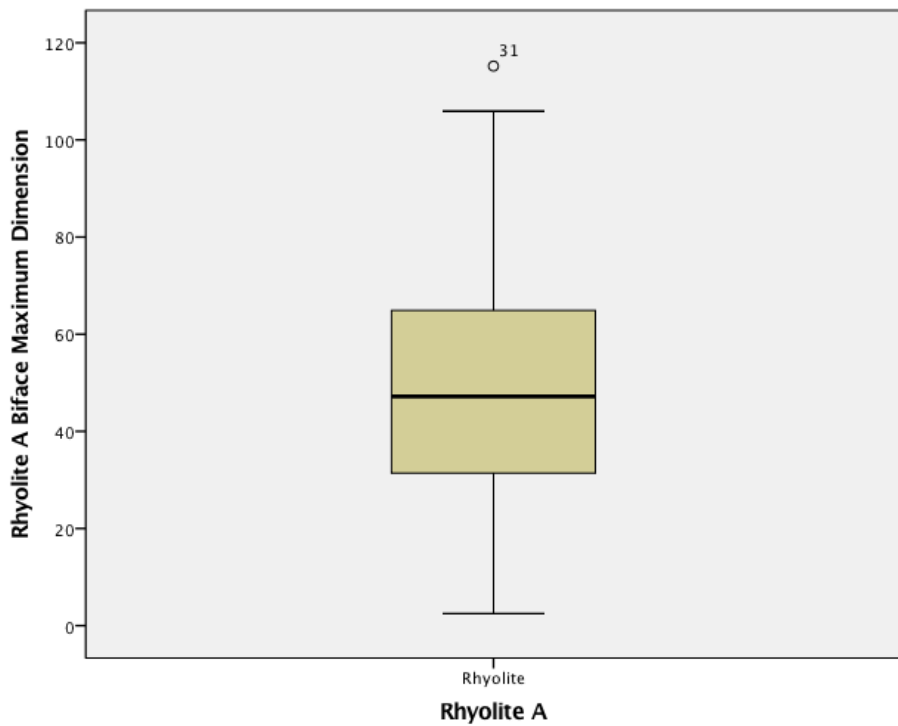


Figure 4.31 Boxplot showing the median, quartiles, and extreme values of the maximum dimension of bifacial artifacts made of group A rhyolite

Discussion

OFT Hypothesis

The first result to address is the lack of support for my initial expectations based on Optimal Foraging Theory. There was no statistically significant negative linear relationship between material amount and the cost to obtain it, except for Wiki Peak obsidian, which had a weak correlation between the two variables. This means that a pattern reflecting high percentages of low cost material and low percentages of high cost materials was not apparent.

The failure of these tests to meet my expectations does not necessarily mean that prehistoric humans were acting inefficiently. It is likely this model of Optimal Foraging Theory is not sufficient for explaining the variables associated with raw material procurement, transport, tool making, and discard. It is possible that there are more complex scenarios that reflect humans acting efficiently than the model based on raw material weight and cost to travel from the source. The most common critique of OFT is that it does not take into account the complexities of prehistoric foraging (Smith 1983: 637). This study suggests that the limitations are not necessarily in OFT itself, but rather how the theory was tested with the archaeological data. There are distinct limits to the archaeological data available in this study such that it forces me to vastly oversimplify prehistoric foraging by only looking at cost from source to site based on distance and slope.

The first limitation is in the calculation of travel costs. I only use two variables, distance and steepness of terrain (slope), to calculate the energy expenditure associated with raw material acquisition. Other variables that may affect the cost of travel are the use of bodies of water (rivers, lakes, swamps) and the presence/absence and amount of vegetation or snow cover, which

varies seasonally. The cost values I obtained thus may not adequately represent the actual costs experienced by the prehistoric people travelling between source and site of deposition.

An even more important limitation is the nature of the archaeological record is such that we cannot track the entire life history of an artifact by following its movement across a landscape, but rather we are confined to knowing only its source and the place it ultimately entered the archaeological record. Therefore, this study is unable to take into account any circumstance when raw material did not follow a direct path from collection to discard, such as in the context of trade or long episodes of use when a tool was carried to multiple locations within its user's foraging territory.

Additionally, this study assumes when people collected the raw material from the source the ensuing activities were specifically designated for tool manufacture and does not account for the process of procuring raw materials being imbedded in other foraging activities. For instance, the model does not expect humans to collect raw material in the course of a hunt, where the hunting process rather than the weight of the material primarily dictates where the individuals will transport the material. This assumption could contribute to failure of the data to meet my expectation based on ethnohistoric and ethnographic evidence from Alaska as discussed in Binford (1979). Binford (1979) indicates that raw material was acquired opportunistically in the course of other activities, and therefore the lithic studied here may have made several "stops" before being deposited.

Why Use High Cost Rhyolite instead of Obsidian?

The failure of the results of Batza Téna obsidian and group A rhyolite to conform to the hypothesized pattern begs the question, if people could transport material from Batza Téna to most of the sites (n=31) at less cost than transporting material from Rhyolite A why would people have used group A rhyolite material? Additionally, if obsidian is easier to flake than rhyolite and therefore preferred for detailed tool manufacture, then obsidian should always be present at sites that have a low cost from Batza Téna and also should be present in the form of formalized artifacts and microblade technology. This expectation was not met by the results of material cost analysis. Moreover, if Batza Téna is preferred for the manufacture of formalized artifacts and microblade technology these tools made of Batza Téna obsidian should be present at sites with a high cost from Rhyolite A. This expectation is met in one instance by site CIR-00 029. Further, if Batza Téna obsidian was preferred Batza Téna obsidian may occur at sites low cost from the Rhyolite A source as if this material is replacing the group A rhyolite material. This expectation was also not supported. There are several aspects if these expectations that could lead to their failure to be supported such as, the material being used because of the proximity of its source to other foraging activities, and the immediate need for a tool regardless of the material.

To address these unmet expectations first it is important to remember why group A rhyolite has a high cost in this model. Recall that Tobler's Hiking Function takes slope and distance into account when calculating the cost to travel from the source. Batza Téna is far, in terms of Euclidean distance, from the sites in the central Tanana River Valley but it is located in rolling hills, which do not require strenuous hiking. Therefore, the lack of steep slopes between

the Batza Téna source and the sites in the Tanana Valley makes this raw material actually less costly than Rhyolite A, which is located in steep, rocky mountains of the Alaska Range. People would have had to traverse sharp ridges (at times hand over hand) to transport group A rhyolite from the source to the sites. Tobler's Hiking Function accounts for hand-over-hand climbing as being exponentially more costly than a slope that one could just walk. Therefore, even though Rhyolite A is located much closer to the central Tanana Valley sites, the sites have a much higher cost from this source because of its location in steep terrain. However, if people were using this raw material source while on hunting expeditions the cost of procuring raw material is embedded in the hunting activity and the cost of this task is not possible to isolate.

This premise may offer an explanation for the lack of a relationship between Batza Téna and Rhyolite A material amount and their cost, and also the use of the costly Rhyolite A when less costly Batza Téna obsidian was available. Evidence for this premise is based off of ethnographic accounts that describe people opportunistically obtaining toolstone while hunting, rather than making individual trips between toolstone sources and the sites for the sole purpose of collecting raw material. According to Binford's (1979) account of the Nunamiut (of Anaktuvuk Pass, north-central, Alaska) he describes that the collection of raw material used to make tools as embedded procurement, part of basic subsistence activities. Binford (1979) gives the example of a common account of how the Nunamiut performed this task.

When a fishing party camps at a lake and fishing is slow, a group of members of the fishing party may walk 3.75 miles southeast to a mountain where there is raw material quarry, collect toolstone, walk up to the top of the mountain and scan the landscape for

game while knocking off stone cortex to make cores, then carry the cores back to the fishing camp and eventually back to the residence (Binford 1979: 259).

It is clear from this case that toolstone collection and transport was likely to have been an extra journey in the course of other foraging activities.

According to this example, if Tanana Valley foragers behaved similarly to the Nunamiut described by Binford, it was likely that they would have sent hunting parties into the Sugarloaf Mountain area. It is possible while the hunters were scouting game they picked up group A rhyolite from the source, then transported it to lookouts to where they could watch for game and process the raw material. Further, some of the tools and left over cores made in the mountains likely were carried down to the sites in the valley, which would account for the group A rhyolite artifacts in these valley assemblages. Additional support for this reasoning is described by Guthrie (1983) when he refers to sites in the mountains as “bluff-top lookout” sites, which are thought to be hunting camps where small groups were sent out from the villages in the river valley bottoms to watch for game. Yesner (2001) suggests that a few of these sites may have evidence for longer occupation but in most cases the assessment by Guthrie (1983) is accepted. A discussion of how the tool assemblages at each site may be evidence for this subsistence and mobility pattern is found in, *Patterns of Mobility and Rhyolite Use*.

Other Rhyolite and Obsidian Sources, and Geochemical Groups

It is likely that raw material procurement was opportunistic and combined with other subsistence practices (hunting). Further evidence for this procurement strategy is that some artifacts in the Tanana River Drainage that are not sourced to Batza Téna, Wiki Peak, or Rhyolite A. These materials include 19 other geochemical groups that make up the obsidian artifacts and nine other geochemical groups that make up the rhyolite artifacts in the Tanana River Drainage. Each of these groups account for only a small percentage of Tanana River Drainage artifacts, but the diversity of sources used speaks to the variety of raw materials available and exploited by Tanana River Valley foragers. A quote by Jessie Ahgook, one of Binford's Nunamiut informants, states, "catch things when you can, if pass good stone for tools, pick 'em up, if pass good wood for sled runner, catch 'em then" (Binford 1979: 258). This example suggests that while group A rhyolite was most often used, if other sources of rhyolite were encountered individuals would not relinquish the opportunity to collect the other material.

Rhyolite A, Batza Téna, and Wiki Peak materials are likely to dominate the Tanana River Drainage archaeological record because they were identified on the landscape and exploited repeatedly during foraging activities. However, if foraging activities did not take people bring people into contact with one of these three sources, other materials could have been exploited without a problem. Another account from Binford (1979) offers a relevant example that addresses both the use of these other materials in the Tanana River Drainage and supports the opportunistic exploitation of Rhyolite A, Batza Téna, and Wiki Peak. Binford (1979) calls tools that are expediently assembled for a specific task "situational gear," which are always created in

response to events rather than in anticipation of them. He gives the following example from an Eskimo informant when he was a young man:

“The young man and his uncle were hunting. They had guns and a western knife with them. They came across a herd of caribou in a lake and shot a number of them. When they went to butcher the game they realized they had lost the knife. Without any sweat the uncle, who had grown up using stone tool technology rather than metal, walked around the lake until he found toolstone quality stone (something good enough) and made a bunch of small knives. Without any problem the two men butchered the caribou with the expediently formed tools” (Binford 1979: 266).

This example indicates that if the Tanana Valley foragers acted similarly populations of foragers in Northern Alaska, not one source of raw material was so crucial for tool manufacture that a special trip to procure it would be necessary if other useable materials were available on the foraging route. Though the present data cannot conclude why these three raw material sources dominated the Tanana River Drainage assemblages there are several possible explanations. One explanation is the large amount of certain materials, such as group A rhyolite, could be due to them being located in a resource rich area (good hunting grounds) and therefore people were in contact with them more during the hunting rounds. The presence of other materials could be a result of different foraging expeditions. Another explanation could be that certain materials such as Rhyolite A, Batza Téna obsidian, and Wiki Peak obsidian were preferred for tool manufacture and would be exploited the most often.

Patterns of Mobility and Raw Material Use

It has been argued that prehistoric hunter-gatherers were likely to have opportunistically exploited raw material sources in combination with other foraging activities, since group A rhyolite was used despite having a high cost from most sites. As apparent in figures 4.13, 4.14, and 4.15 most of the sites containing group A rhyolite occur in the mountains near the Rhyolite A source and the central Tanana Valley along the river, while sites containing Batza Téna and Wiki Peak obsidian chiefly are distributed along the Tanana River.

This patterning of sites begs the question, what kind of mobility and subsistence patterns led to the distribution of these materials in the site assemblages. Chris Houlette (2009) discusses prehistoric mobility patterns based on ethnohistoric research and studies of the distribution of obsidian in the Gates of the Arctic National Park, Brooks Range, Alaska. He suggests that if people exploited the environment similarly in the past as described in ethnohistoric accounts, people traveled the most convenient/efficient routes based on the season throughout the territory of Gates of the Arctic National Park, such that people foraged along ridgelines in the summer and along frozen rivers in the winters.

Based on the evidence described by Houlette (2009) and the tool types present in the 35 relevant site assemblages I chose for analysis, I propose that the mobility patterns that are represented by the archaeological record could be the seasonal movement of Tanana Valley foragers. I suggest that these prehistoric foraging groups hunted in the mountains around Rhyolite A in the summer and traveled along the frozen Tanana River in the winter, coming into contact with Batza Téna and Wiki Peak obsidian. The distribution of tool types of each material in the site assemblages supports this hypothesis.

However, without knowing all the dates of the artifact components of each site or prehistoric cultural boundaries, the distribution of rhyolite and obsidian could also be attributed to other factors. For instance, the distribution of these materials could represent two different mobility strategies separated temporally. This scenario could have been that early foragers hunted along the rivers collecting and using obsidian, possibly utilizing a residential mobility strategy, and later foragers could have utilized a logistical mobility strategy, sending hunting expeditions from a permanent/semi-permanent residence into the mountains, collecting group A rhyolite, then returning to the sites in the valley. The sites that are dominated by either obsidian or rhyolite may represent the different time periods, and the sites that contain both materials could be sites that were occupied repeatedly throughout history. The existence of two different cultural groups cohabiting the Tanana River Valley could create the same scenario such that one group foraged along the Tanana River using obsidian, and another exploited resources in the mountains using rhyolite. Therefore, the sites that contain both obsidian and rhyolite could be due to the two groups interacting.

Rhyolite Stone Tool Form and Site Function

I speculate that prehistoric hunter-gatherers in the Tanana River Drainage foraged in the summer in the Sugarloaf Mountain area and while nearby, collected Rhyolite A for use in stone tool production. They appear to have made and used tools for hunting in the mountains and carried some tools and raw material back to residences in the valley. Evidence for this subsistence strategy will be presented in this section by comparing the artifacts present in individual site assemblages. The site assemblages containing group A rhyolite in the mountains

are compared to assemblages containing group A rhyolite in the Tanana Valley. These assemblages are included in the 35 relevant sites that contain 10 or more artifacts or 20 or more grams of material shown in Figures 4.13, 4.14, and 4.15.

Examination of the site assemblages shows that the types of rhyolite lithics at a site are heavily dependent on their distance from the source. The sites in the mountains clustered around the Rhyolite A source are dominated by bifacial technology (bifaces and projectile points) and debitage, (Table 4.7). Debitage makes up 61% of all the artifacts in these mountain sites, and 28% of the artifacts are bifacial technology, while only 1% is unifacial technology. The debitage consists mainly of interior flakes, which lack cortex. The lack of cortex means that the outside of the rock had already been removed and the people were working on the next stage of tool making, which is the actual formation of a tool. The dominant presence debitage and bifaces in these assemblages indicate the formation of hunting tools, which is consistent the discussion by Guthrie (1983), that most of these sites in the mountains were “bluff-top lookout” hunting camps rather than residences.

Valley sites show slightly more artifact variety than the mountain sites, but most importantly they are clearly dominated by a different set of lithic types including, unifacial tools, microblade cores, and some debitage (Table 4.8). Debitage makes up 54% of the artifacts in Tanana Valley sites, 20% of the artifacts are unifacial technology, 14% are microblade cores, while only 9% is bifacial technology. This pattern of lithic technology may indicate that the sites that were dominated by Rhyolite A in the Tanana Valley served a different purpose than the sites in the mountains. Unifacial tools are often understood as tools for meat processing, hidescraping, and boneworking (Shott and Scott 1995:53-54). Microblade cores are essentially formally

manufactured artifacts formed to be able to efficiently make several microblades, or otherwise store the material in a convenient form until it is needed. I interpret the sites in the valley dominated by Rhyolite A unifacial technology to be residential sites or places where time consuming tasks were carried out. A possible scenario of the behavior represented by this pattern is that people may have killed and partially butchered the game in the mountains, then transported it to the valley in order to process the meat and hide.

Obsidian Stone Tool Form and Site Function

The distribution of sites containing only obsidian along the Tanana River reflect the pattern of movement of foragers along the frozen Tanana River I hypothesized based on ethnohistoric travel routes described by Chris Houlette (2009). The lithic tool types that make up these sites provide information of how the obsidian, particularly Batza Téna obsidian was used. Debitage makes up 70% of the obsidian artifacts from the obsidian assemblages in the Tanana Valley (Table 4.9). These sites also contain a variety of types ofdebitage, such as bifacial pressure flakes in addition to interior flakes, which suggests the manufacture of bifacial technology. However, bifacial technology only makes up 1% of these site assemblages, and unifacial technology makes up 6% of the assemblages, while microblades make up 20% of the assemblages.

It is difficult to conclude from these results what kind of subsistence pattern these assemblages suggest. Without the dates of the assemblages it is impossible to determine if the tasks performed with obsidian tools were different than rhyolite and varied seasonally, temporally, or culturally. The presence of unifacial technology, microblade technology, and

bifacial pressure flaking debitage in these assemblages could indicate that multiple activities occurred at sites in the Tanana Valley dominated by obsidian, such as the manufacture of tools and the processing of meat and hides.

The last aspect of the tool assemblages in the Tanana Valley that needs to be discussed is the purpose of the sites that contain both Batza Téna obsidian and rhyolite in roughly equal quantities. These site assemblages are shown in Figures 4.16 through 4.23. There is not a clear pattern associated with the tool types in these site assemblages, compared to the pattern visible of the sites in different locations (mountains verses river valley). Figures 4.3 and 4.5 show the percent of lithic types by all the obsidian and by all the rhyolite in the Tanana River Drainage. The assemblages shown in Figures 4.16 – 4.23 do not particularly deviate from the overall tool type breakdown of these two materials. Further, the more specific patterns of lithic types at these sites are representative of the other sites containing either obsidian or rhyolite in the valley, such that there are many microblade cores and unifaces made of rhyolite (Tables 4.10 and 4.11). These sites that contain both obsidian and rhyolite could be the result of material being conserved between seasons, multiple occupations throughout history, or interaction between cultural groups.

Obsidian Trade

I discussed that group A rhyolite may have been opportunistically collected while prehistoric hunter-gatherers were foraging in the mountains during the summer, and Batza Téna and Wiki Peak obsidian could have been obtained in the winter as hunter-gatherers followed game longer distances up and down the frozen Tanana River. It is possible that foragers traveling

along the Tanana River could have directly collected Batza Téna and Wiki Peak obsidian. However, since Batza Téna over 300 miles from the central Tanana Valley, it is possible that the cost to collect Batza Téna obsidian was reduced by trade.

The longer travel distances along the river in the winter could have brought foragers exploiting the resources of the Tanana Valley in contact with foraging groups exploiting the environment around Batza Téna. Thus the groups could engage in trade of the Batza Téna obsidian. The same pattern could be true for Wiki Peak obsidian. Without knowing cultural boundaries, the function of sites between the Batza Téna source and the Tanana River Drainage (not within the study area), and the dates of these sites it is not possible to establish that obsidian was traded.

However, studies have suggested that obsidian was a valuable commodity that was traded throughout Northeast Asia (Kuzmin 2013) and traded as early as 11,600 BP in Southeast Alaska and British Columbia (Dixon 2001). The idea of obsidian trade across Alaska, especially from Batza Téna and Wiki Peak, has been heavily studied and discussed (Reuther et al. 2011:282). Houlette (2009) considers evidence for Batza Téna obsidian trade in the Brooks Range 56 miles from Batza Téna itself. He noted that prehistoric sites containing Batza Téna obsidian were located along the same Athabascan and Eskimo ethnohistoric trade routes from the 19th century. This evidence suggests that prehistoric foragers used the landscape similarly to the ethnohistoric accounts. Historic accounts have revealed that Batza Téna obsidian was traded. Batza Téna was located within Athabascan territory but Batza Téna obsidian is present in prehistoric sites in Eskimo territory. Though these results are not conclusive Houlette (2009) assumes this information suggests the prehistoric trade of the material. The trade of Batza Téna obsidian is

commonly accepted due to the estimated size of prehistoric foraging groups in Alaska, extensive distance Batza Téna obsidian traveled would have most likely required exchange networks (Cook 1995:95; Clark 1995:89-90; Reuther et al. 2011).

Obsidian Conservation

Another interesting aspect of this data set tells us Batza Téna obsidian and group A rhyolite were possibly used or valued differently. One major difference between obsidian tools and rhyolite tools is that rhyolite tools in the whole dataset tend to be heavier than obsidian tools (Table 4.12). In particular, group A Rhyolite bifacial technology is, in most cases, much heavier and larger than Batza Téna obsidian bifacial technology (Figures 4.28 – 4.31). The same pattern is apparent between Rhyolite A and Batza Téna unifacial technology (Figures 4.24 – 4.27). Given the effort required to make formalized tools, and the specialized tasks they were designed for, bifaces (including, projectile points, and knives) are more likely than other tool types to be reused and perhaps resharpened (Kelly 1988:718). As a tool is refurbished, it becomes smaller and lighter, therefore tools with lengthy life histories and multiple resharpening occasions may be significantly lighter and smaller than a “new” tool of the same type. There are several possibilities that could lead to group A rhyolite bifacial and unifacial tools being heavier and larger than these Batza Téna obsidian tools. These possibilities include, preference and need to conserve Batza Téna obsidian, edge holding qualities of each material, and the original size of raw material used to make the tools.

Since the maximum dimension and weight of the same type of bifacial and unifacial tools are less for Batza Téna obsidian than Rhyolite A, there may have been a need/preference to

conserve the Batza Téna material (and a value associated with it). If Tanana Valley foragers obtained Batza Téna material through trade it could have had an economic or cultural value associated with it that would constitute tools being made smaller in order to conserve material. It is difficult to determine the economic and cultural/spiritual value of these materials from this data, however it is a facet of archaeology that is often considered with respect to the use of raw materials (Gould 1980:141). As described in the results there are also a significantly greater number of formalized tools made of rhyolite in the Tanana River Drainage sites than that of obsidian (Table 4.12). One possible interpretation of this information is that if Tanana Valley foragers did not have to trade for Rhyolite A, they could access the source on their own terms, make larger tools and discard them more readily, rather than conserving them until the next trade encounter. However, it could also be that archaeologists have not found as many obsidian formalized tools in the assemblages, even if more exist, because they were being used and were discarded in locations that have not yet been located.

On the contrary, another potential reason for the difference in size and weight of obsidian and rhyolite tools is that these materials hold cutting edges differently. While obsidian is sharper than rhyolite, obsidian becomes dull much faster than rhyolite (Smith 1999). Therefore, it may have been necessary for prehistoric people to resharpen the Batza Téna obsidian tools, which makes them smaller, while Rhyolite A tools may hold an edge for longer and subsequently not require as much resharpening.

Finally, the nature of the size of the raw Batza Téna stones that are collected from the source verses the size of the rhyolite stones that were collected could be the cause of the difference in size and weight of the two materials. If pieces of group A rhyolite raw material

were large enough, an individual could make several smaller tools or one large tool from one piece of raw material. Batza Téna pebbles and cobbles are described as golf ball to baseball size by Patton and Miller (1970:761), therefore the size of tools one could make is limited.

I propose that the size of the raw material and the need for resharpening the obsidian material likely are the causes for this difference in tool sizes of these two materials. Moreover, the presence of Batza Téna biface preforms in the Tanana River Drainage assemblages suggest that not all Batza Téna material was used up entirely before discard. Biface preforms are unfinished tools that are the initial stages of manufacture of material to be made into a biface. Additional analysis of amount of retouch on tools and debitage of each material could validate this hypothesis.

Conclusions

The Tanana River Drainage in interior Alaska was one of the earliest places inhabited by humans North America. Humans exploited the resources in this area for the past 14,000 years. Prehistoric hunter-gatherers employed subsistence strategies to survive and thrive in the harsh subarctic environment, which involved hunting and foraging, raw material procurement and stone tool manufacture, and interaction with other hunter-gatherer groups. This study attempts to offer a preliminary understanding of prehistoric subsistence strategies in the Tanana River Drainage, especially with regard to stone tool procurement and the role of different igneous raw materials. While the reasons for raw material preference between obsidian and rhyolite cannot be definitively determined from the dataset, the pattern of distribution of the two materials may suggest the instances when one was used rather than other.

The hypothesis based off of Optimal Foraging Theory stated if prehistoric hunter-gatherers were foraging efficiently than they would be expected to use raw material with the lowest cost of acquisition, However, it was not sufficient to explain the complexities of the raw material procurement, which was likely part of other subsistence patterns of the prehistoric people in the Tanana River Drainage. The expectation that if the people were acting efficiently and acquiring the lowest cost raw materials then there would be a negative linear relationship between material amount (weight) and material cost was not met. However, rather than concluding that prehistoric hunter-gatherers in this region were not acting efficiently, patterns in selected site assemblages in combination with previous ethnographic accounts suggest more complex subsistence strategies.

Though the data is limited, especially with respect to dates of artifact assemblages, it is apparent that group A Rhyolite material was exploited even though it had a higher cost to transport from the source than Batza Téna obsidian. I suggested that the high cost of Rhyolite A material is due to its location in the mountains, while Batza Téna is located in rolling hills, north of the Tanana River Drainage. Since sites in the mountains near the Rhyolite A source are dominated by this material, I propose that the cost of procuring group A rhyolite is embedded in other foraging activities in the mountains. This makes it difficult to assign a cost to a stone tool based on its distance from the raw material source since it likely did not follow a direct path from its source to ultimate location of deposition. Observed differences in raw material and tool type between mountain and Tanana Valley sites suggest different tasks were carried out in each location. For instance, rhyolite bifacial technology in the mountains implies hunting, while unifacial technology in the valley implies processing. Additionally, site assemblages dominated by obsidian are distributed along the Tanana River, contrary to the sites dominated by rhyolite, which are mainly distributed in the central Tanana Valley and in the mountains around Rhyolite A.

These observations are consistent with ethnographic observations suggesting that foragers gathered and stored raw material opportunistically and exploited the terrain seasonally. Therefore, I indicate that the use of the two materials may be a result of prehistoric seasonal foraging patterns, such that group A rhyolite was exploited while hunter-gatherer groups hunted or foraged in the mountains during the summer, and Batza Téna and Wiki Peak obsidian were exploited, possibly through trade, as hunter-gatherer groups from the central Tanana River Valley followed game a longer distance up and down the frozen Tanana River in the winter. The

sites that do contain both obsidian and rhyolite may potentially have been larger/longer term residences. However, without the dates of the site assemblages, and knowledge of cultural boundaries it is not possible to truly assign the differences in the distribution of raw material to seasonal subsistence patterns. Changes in subsistence strategies over time or differences in cultural groups' subsistence strategies could also account for the differential use of these raw materials. These are the conclusions based on the initial examination of a large and general dataset. A more in depth analysis with artifact dates and site function would contribute to confirming the seasonal interpretation.

Future Considerations

This project is a preliminary study of the distribution of rhyolite and obsidian stone tools in relation to their raw material sources in the Tanana River Drainage. The goal of this project was to introduce methods for comparing the two raw materials and offer initial interpretations of prehistoric human behavior based on these results. More information is needed to provide conclusive evidence for the interpretations made in this study. This information includes dates of the artifact assemblages, uniform lithic classification scheme at the most detailed level, and absolute time values for traveling from the sources. In future studies the limitations of the dataset and the analysis may be addressed by examining each site assemblage included in the Tanana River Drainage portion of the AAOD and rhyolite dataset in order to gain more complete artifact information (lithic classification, weights, maximum dimensions, types, and most importantly dates if possible). Commonly, archaeological studies of individual sites can focus on understanding site structure through the site's artifact composition. Therefore the lithic assemblage is understood in the context of the site (Kunz and Reanier 1995; Odess and Rasic 2007). This approach is beneficial because the analysis of the artifacts can be concentrated on specific attributes of individual tools, such as the degree of use and retouch. If applied to this study, this information, in addition to a site's context and function, could be used to reassess and add detail to the conclusions made in this thesis.

In the next two years further investigation of this dataset and modifications of the methods of analysis could result in a master's thesis project. In the immediate future, it is a priority to generate cost values in ArcMap that are representative of absolute time rather than

relative time. Further investigations would entail, a closer examination of each site and lithic assemblage, such as reading site reports, which would add to the interpretation of site function. Additionally, every lithic of each site in the Tanana River Drainage needs to be geochemically analyzed and assigned a group, since some of the rhyolite data was sampled. The Rhyolite A source needs to be “pin-pointed” on the landscape and other sources of rhyolite and obsidian need to be located. It will also be necessary to assess the affect of these obsidian and rhyolite sources on the distribution of artifacts in site assemblages, and subsequently the affect of other materials, such as chert and chalcedony, on lithic assemblages. Next, determining the presence/absence and amount of cortex present on the lithics would offer a less biased avenue for evaluating raw material in relation to transport cost because cortex is essentially useless material that would take more energy to carry. Situations may warrant stone with cortex being carried away from the source, such as not having time to chip the cortex off of a stone, but in general one would expect to find amounts of cortex to decrease as cost distance from the source increases. There was complete information on the cortex absence and presence of rhyolite lithics but incomplete information on that of obsidian. A reanalysis of the distribution of artifacts with cortex using complete information would be beneficial for testing the original hypothesis.

The methods of this analysis began broad with a huge amount of general artifact data that was broken down into a manageable dataset for a spatial study, however I suggest that the next stage of this project should begin by understanding the function of the tool assemblages of the sites in the Tanana River Drainage.

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Appendix A: ArcMap 10.3 Steps to calculate travel cost using Tobler's Hiking Function

The base-map of Alaska was created using USGS Land Cover 100 Meter Resolution – Alaska, Albers Projection map. The Digital Elevation Model (DEM) used was USGS Elevation, Color-Sliced – Alaska 100 Meter Resolution Albers Projection map. The geographic location of the raw material sources (Batza Téna, Wiki Peak, and Rhyolite A estimation) was proved by the Museum of the North as shapefiles. The latitude and longitude of sites in the Tanana River Drainage were also provided by the Museum of the North in the AAOD and Alaska Rhyolite Database, which were added as XY data to ArcMap. The projection used throughout the project is Alaska Albers NAD 1983 (2011).

Tobler's Hiking Function Path Distance Process:

The DEM was clipped to the size of the study area: Catalog: right click to create a new shapefile. Select polygon from the drop down menu. Go to environments to make sure the new polygon's projection is the "same as display." Save the new shapefile and export as a layer on the map. Right click on the new shapefile in the table of contents, choose editor, start editing, select the shapefile in the popup display and choose polygon, then outline the study area, when the polygon is drawn stop editing and save edits. Export the new polygon as a shapefile and save to your geodatabase (.gdb). Search for Clip (Coverage) and use the new shapefile to clip the DEM so the following analyses are not calculated for cells of the map that are not needed.

Input Coverage: my DEM

Clip Coverage: new polygon shapefile (analysis extent)

Output Coverage: Save the clipped DEM to my .gdb

Begin following steps of Kaitlin Yanchar's ArcGIS Tutorial: <http://kaitlinyanchar.com/arcgis-tutorial-toblers-hiking-function/> accessed: March 29, 201. Calculate the anisotropic cost (minutes) of walking away from each source location using the Path Distance function in ArcMap.

In this study a 100 meter resolution DEM was used instead of a 30 meter resolution DEM. First calculate slope from the DEM using Spatial Analyst Tool, Surface, Slope function, which creates a raster. File, Add Data to import Tobler's Hiking Function vertical factor table calculated in Excel into the ArcMap Table of Contents. Check to make sure the table contains all the values. It may be necessary to use Excel to Format Cells and define the proper number of decimal places before saving as a text file. Then use Spatial Analyst tool, Distance, Path Distance Function to calculate the cost to walk across the surface in the form of a gradient raster.

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Appendix B: Lithic Classification Categories

The following is the break down of how I classified the artifacts from the AAOD and the Alaska Rhyolite Database. The first two columns are the different lithic descriptions encountered in each database according to the material they referred to. The following columns are headed by the categories I created and the original lithic descriptions that I designated to these categories are below the header.

Lithic Classification Categories

Obsidian

- Bifacial percussion flake
- Bifacial pressure flake
- Interior flake
- Microblade
- Nondiagnostic flake fragment
- Primary decort flake
- Second decort flake
- Uniface
- Flake
- Bifacial
- Core fragment
- Projectile point – Chindadn
- Projectile point – Notched
- Utilized
- Flake tool
- Projectile point – other
- Biface Preform
- Burin Spall
- Core Tablet
- Bipolar flake
- Blade
- Projectile point – Lanceolate
- Tested Raw Material
- Unpatterned (flake) core
- Projectile Point – Stemmed
- Linear flake
- Projectile point – Fluted
- Biface – Knife
- Blade tool
- Graver
- Projectile point – Side/end blade
- Biface Fragment
- Flake – bipolar
- Microblade – Medial
- Core debris
- Microblade core

Rhyolite

- Adze
- Uniface
- Utilized flake
- Biface fragment
- Blade
- Core tablet
- Interior flake
- Microblade
- Unifacial tool
- Retouched flake
- Cortical spall
- Secondary cortical spall
- Unidentified flake
- Projectile Point
- Biface
- Blade-like flake
- Core
- Core debris
- Microblade core
- Chindadan Pt.
- Undiagnostic Flake
- Biface mid-section
- Core tablet --Microblade tech
- Burin/interior flake --micro tech
- Primary spall –Cortical flake
- Core debris –micro tech
- Core fragment –microblade tech
- Face rejuvenation –micro tech
- Burin –microblade tech
- Biface thinning flake
- Secondary spall –cortical flake
- Biface tip

Formalized Artifacts

- Core fragment
- Projectile point – Chindadn
- Projectile point – Notched
- Projectile point – Other
- Projectile Point - Lanceolate
- Projectile point – stemmed
- Projectile point – fluted
- Projectile point – side/end blade
- Blade
- Blade tool
- Biface – knife
- Biface Fragment/Biface Frag
- Graver
- Unpatterned flake core
- Adze
- Uniface
- Unifacial tool
- Projectile point
- Biface
- Core
- Core Tablet
- Chindadn point
- Biface midsection
- Biface tip

Expedient Artifacts

- Flake tool
- Bipolar flake
- Flake - bipolar
- Linear flake
- Utilized flake
- Retouched flake
- Blade-like flake

Debitage

- Bifacial percussion flake
- Bifacial pressure flake
- Interior flake/interior flake
- Nondiagnostic flake fragment/ Undiagnostic flake
- Primary decort flake

- Second decort flake
- Flake
- Tested raw material
- Unpatterned (flake) core
- Core debris
- Cortical Spall
- Secondary Cortical spall
- Unidentified flake
- Core debris
- Primary spall/cortical flake
- Biface thinning flake
- Secondary spall – cortical flake

Microblade Technology

- Burin
- Microblade
- Burin spall
- Core fragment – microblade tech
- Microblade Core
- Burin/interior flake --micro tech
- Face rejuvenation – microblade tech
- Core debris – microblade tech
- Core tablet – microblade tech
- Microblade medial

Appendix C: Unifacial and Bifacial Case Studies

The results of these analyses did not support the preliminary hypothesis nor did they further offer any new information. These tool types were chosen because they had the largest sample size. Eight sites contain Batza Téna unifacial technology and thirteen sites contain Rhyolite A unifacial technology. Six sites contain Batza Téna bifacial technology and nineteen sites contain Rhyolite A bifacial technology. The amount of each of these tool types was compared to the cost to obtain the material that was used to make them. The sample size for Wiki Peak unifacial technology (3 sites) and bifacial technology (3 sites) was extremely small so attention was given to the comparison between Batza Téna and Rhyolite A unifacial and bifacial distribution. In both cases the cumulative weights of the unifacial artifacts and bifacial artifacts were calculated for each site. Each site is associated with a cost in time to travel from Batza Téna and from the Rhyolite A source. These cumulative weights were compared the costs to obtain the material that was used to make the tool. Since it is expected that prehistoric hunter-gatherers should have utilized materials with the lowest cost of acquisition in order to forage efficiently, all the assemblages with a high cumulative weight of unifacial or bifacial technology of a material should be associated with a low cost from the source of that material.

Unifacial Case Study

The unifacial case study also does not support the hypothesis that there will be a negative linear relationship between cost and amount for Batza Téna unifaces (Figure 11.1) but there does seem to be a slight negative linear relationship between unifacial weights and cost of Rhyolite A

unifaces (Figure 11.2). However, neither relationship is statistically significant based on SPSS Pearson's double tailed test of correlation, cf. Tables 7.1 and 7.2.

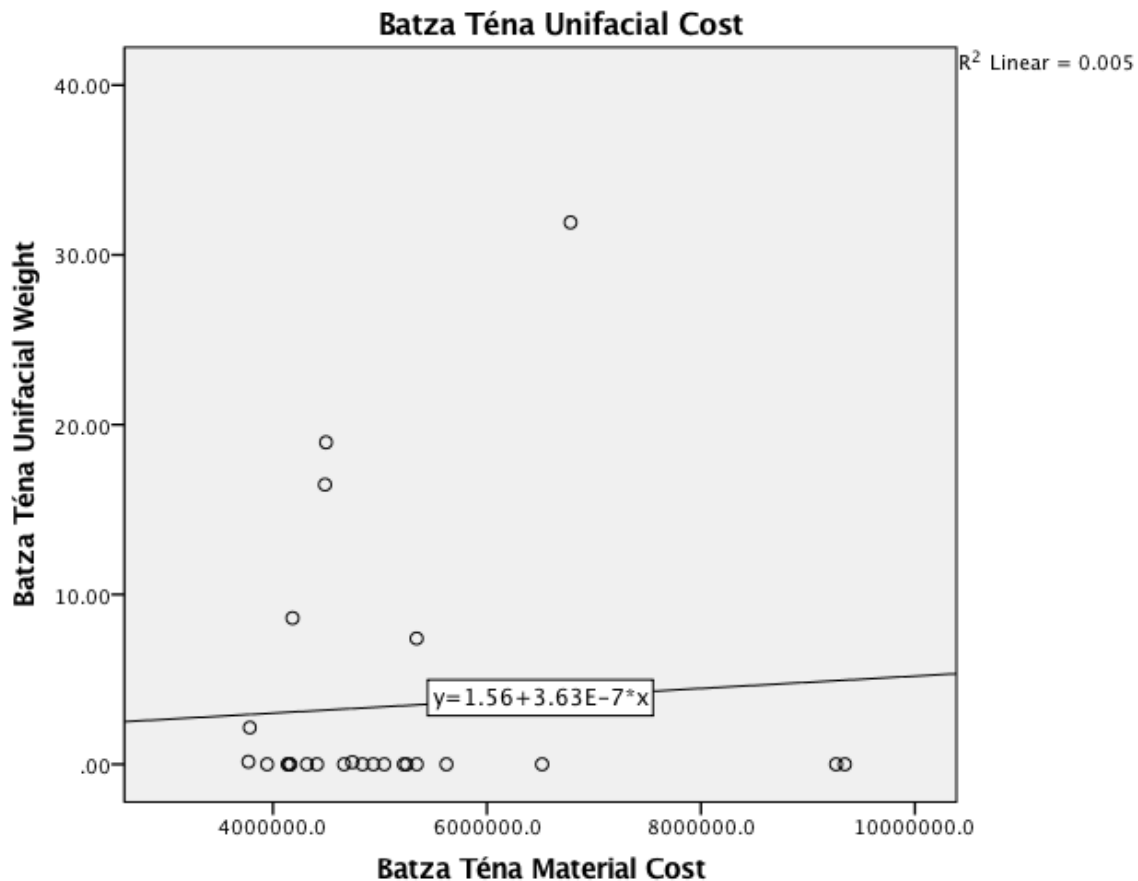


Figure 11.1 Shows the lack of correlation between unifacial technology amount and the cost of the material. The Y axis shows the percent of Batza Téna unifacial artifacts at each site in terms of weight (g). The X axis shows the cost (time) to travel from the Batza Téna source to each site where the artifacts were ultimately discarded.

Table 11.1 Shows the significance of the correlation between the percent of Batza Téna unifacial technology at each site and the cost of transporting the material from the Batza Téna source.

Correlations

		Batza Téna Unifacial Weight	Batza Téna Material Cost
Batza Téna Unifacial Weight	Pearson Correlation	1	.067
	Sig. (2-tailed)		.749
	N	25	25
Batza Téna Material Cost	Pearson Correlation	.067	1
	Sig. (2-tailed)	.749	
	N	25	25

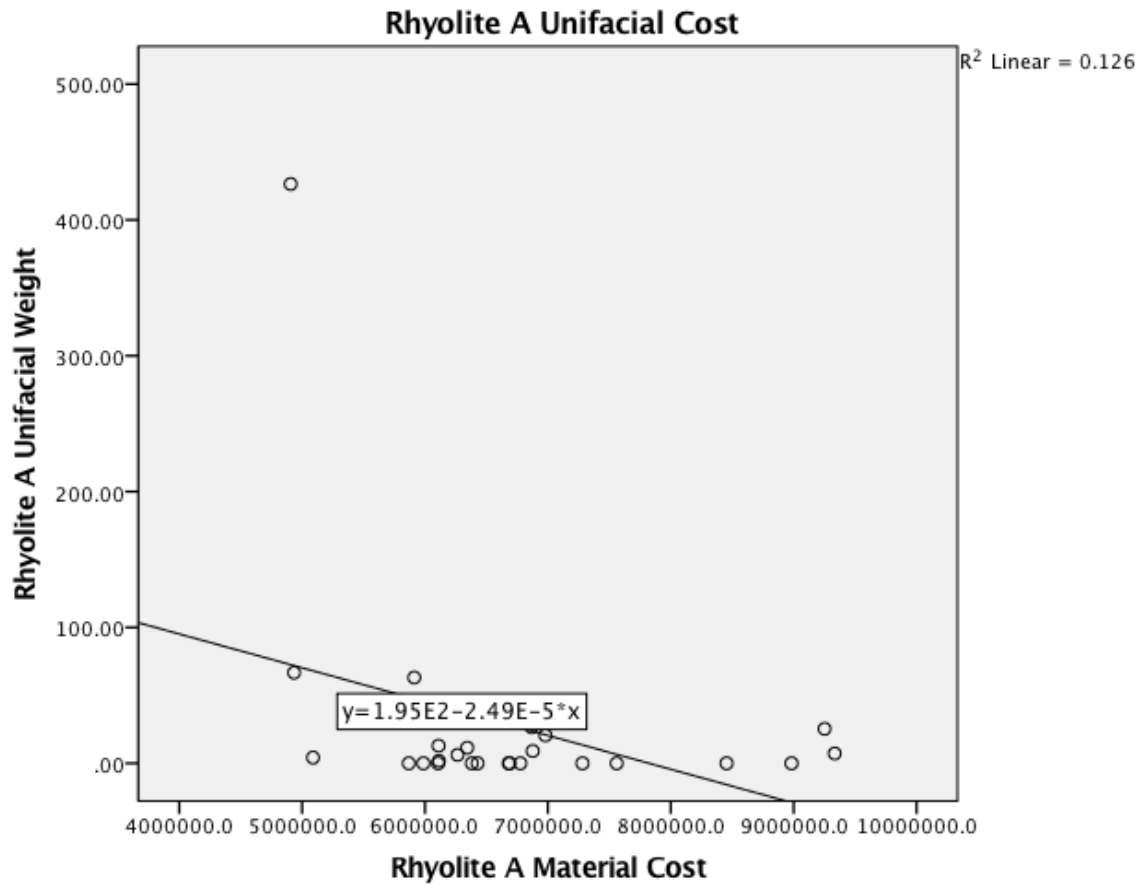


Figure 11.2 Shows the lack of correlation between unifacial technology amount and the cost of the material. The Y axis shows the percent of Rhyolite A unifacial artifacts at each site in terms of weight (g). The X axis shows the cost (time) to travel from the estimated Rhyolite A source to each site where the artifacts were ultimately discarded.

Table 11.2 Shows the significance of the correlation between the percent of Rhyolite A unifacial technology at each site and the cost of transporting the material from the estimated Rhyolite A source.

Correlations

		Rhyolite A Unifacial Weight	Rhyolite A Material Cost
Rhyolite A Unifacial Weight	Pearson Correlation	1	-.354
	Sig. (2-tailed)		.082
	N	25	25
Rhyolite A Material Cost	Pearson Correlation	-.354	1
	Sig. (2-tailed)	.082	
	N	25	25

Bifacial Case Study

Yet again not much can be said to support the hypothesis based off of the bifacial case study. There is a slight negative linear relationship between Batza Téna bifaces and cost (Figure 11.3) but a slight positive linear relationship between Rhyolite A bifaces and cost (Figure 11.4). However, based on Pearson's double tailed tests, neither of these relationships are statistically significant and therefore the variables are not correlated, cf. Tables 11.3 and 11.4.

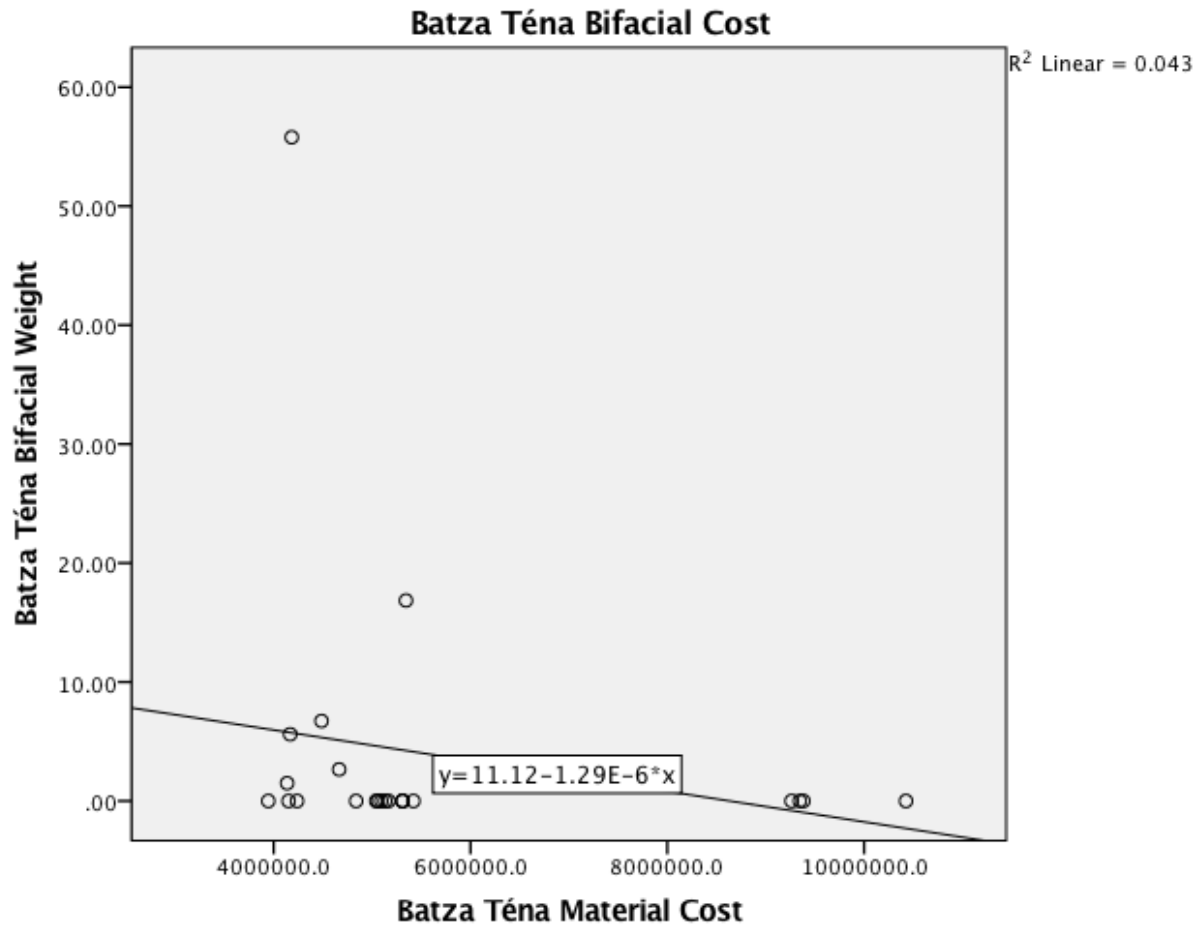


Figure 11.3 Shows the lack of correlation between bifacial technology amount and the cost of the material. The Y axis shows the percent of Batza Téna bifacial artifacts at each site in terms of weight (g). The X axis shows the cost (time) to travel from the Batza Téna source to each site where the artifacts were ultimately discarded.

Table 11.3 Shows the significance of the correlation between the percent of Batza Téna bifacial technology at each site and the cost of transporting the material from the Batza Téna source.

Correlations

		Batza Téna Bifacial Weight	Batza Téna Material Cost
Batza Téna Bifacial Weight	Pearson Correlation	1	-.209
	Sig. (2-tailed)		.340
	N	23	23
Batza Téna Material Cost	Pearson Correlation	-.209	1
	Sig. (2-tailed)	.340	
	N	23	23

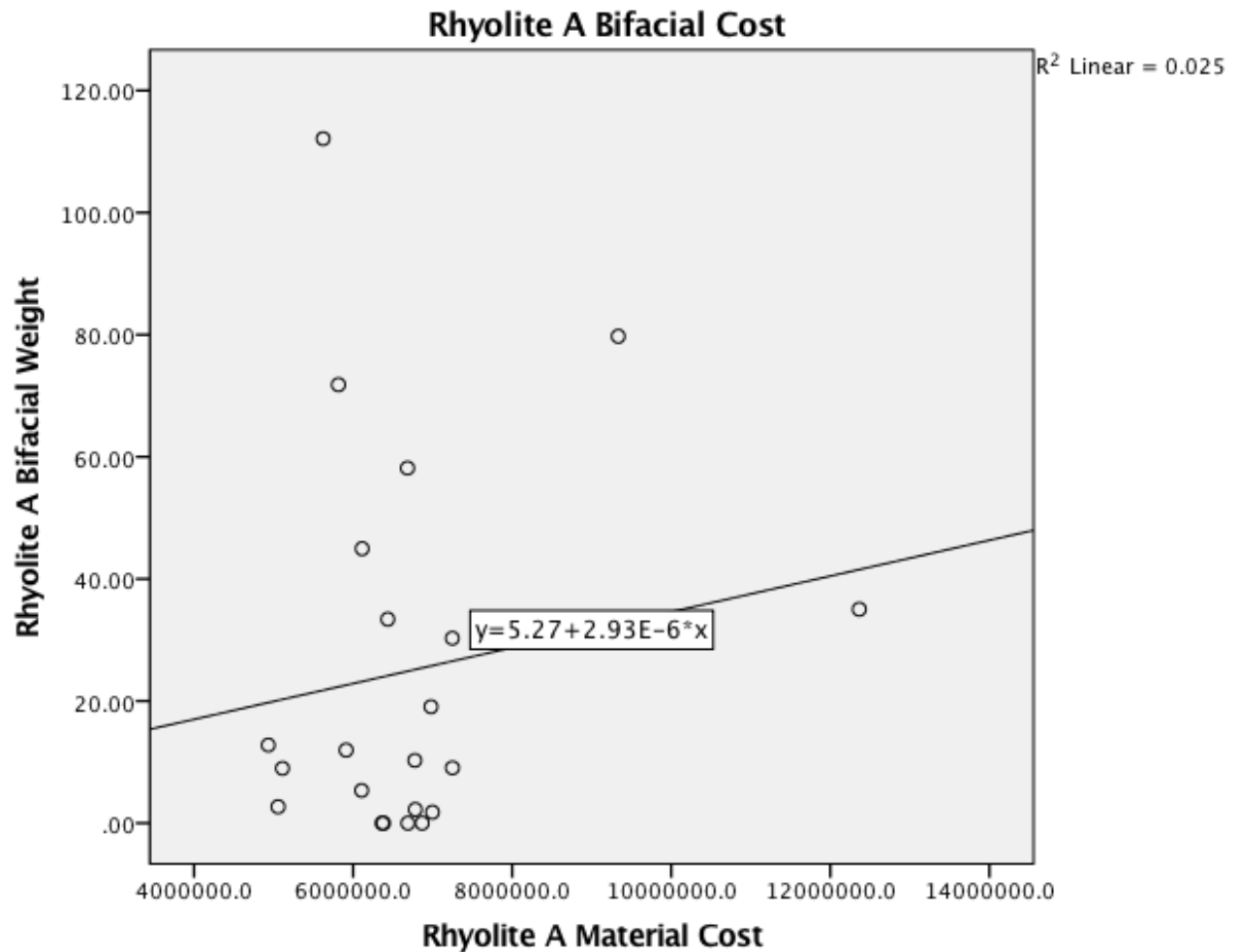


Figure 11.4 Shows the lack of correlation between bifacial technology amount and the cost of the material. The Y axis shows the percent of Batza Téna bifacial artifacts at each site in terms of weight (g). The X axis shows the cost (time) to travel from the estimated Rhyolite A source to each site where the artifacts were ultimately discarded.

Table 11.4 Shows the significance of the correlation between the percent of Rhyolite A bifacial technology at each site and the cost of transporting the material from the estimated Rhyolite A source.

Correlations

		Rhyolite A Bifacial Weight	Rhyolite A Material Cost
Rhyolite A Bifacial Weight	Pearson Correlation	1	.158
	Sig. (2-tailed)		.473
	N	23	23
Rhyolite A Material Cost	Pearson Correlation	.158	1
	Sig. (2-tailed)	.473	
	N	23	23